Technical Report CHL-99-13
August 1999

US Army Corps of Engineers
Waterways Experiment Station

Monmouth Beach, New Jersey: Beach-Fill "Hot Spot" Erosion Evaluation

Report 1
Physical Processes Analysis

by S. Jarrell Smith, Mark B. Gravens, Jane M. Smith

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Prepared for U.S. Army Engineer District, New York

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Report 1 of a series

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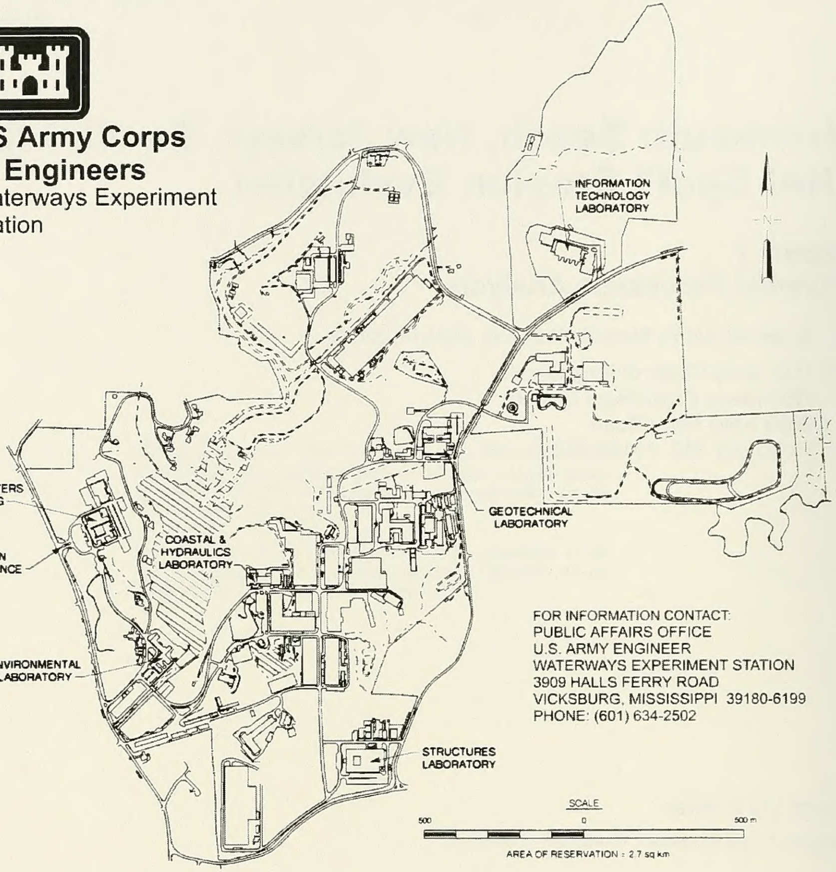

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Preface

In May 1996, the U.S. Army Engineer District, New York (New York District), requested the U.S. Army Engineer Waterways Experiment Station (WES), Coastal and Hydraulics Laboratory (CHL) to evaluate coastal processes and to determine contributing factors for the accelerated erosion of a newly constructed beach fill at Monmouth Beach, New Jersey. Ms. Lynn M. Bocamazo, Engineering Division, New York District, was the project study manager. WES is a complex of five laboratories of the U.S. Army Engineer Research and Development Center (ERDC).

This report documents the subject study, which presented and evaluated hypotheses for the coastal processes contributing to the accelerated erosion at Monmouth Beach. The four hypotheses evaluated in this report are wave focusing by Shrewsbury Rocks, cross-shore beach profile adjustment, beach-fill end losses, and beach-fill planform adjustment. The study concludes by summarizing the evaluation of each hypothesis and presenting conceptual recommendations for mitigation of the high erosion rates.

The study was performed by Mr. S. Jarrell Smith, Mr. Mark Gravens, and Dr. Jane M. Smith, Coastal Processes Branch (CPB), Coastal Sediments and Engineering Division, CHL. Work was performed under the supervision of Mr. Bruce A. Ebersole, Chief, CPB, and Mr. H. Lee Butler (retired), former Chief of the former Research Division. Ms. J. Holley Messing, CPB, coordinated report preparation.

The Director and Acting Assistant Director of CHL were Dr. James R. Houston and Mr. Thomas W. Richardson, respectively.

At the time of report publication, Commander of ERDC was COL Robin R. Cababa, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be conveted to SI units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers

1 Background

The U.S. Army Engineer District, New York (New York District), is constructing Section I - Sea Bright to Ocean Township, New Jersey, of the Atlantic Coast of New Jersey-Sandy Hook to Barnegat Inlet Beach Erosion Control Project (U.S. Army Engineer District, New York 1989). Within the initial portion of this project, a zone of accelerated shoreline erosion has developed near the southern boundary of Monmouth Beach, New Jersey. This report is first in a series on the topic of accelerated erosion rates of the beach fill at Monmouth Beach, New Jersey. The objective of the present report is to identify factors contributing to the area of accelerated erosion at Monmouth Beach. The present study evaluates four hypotheses presented as possible explanations for the hot spot within the beach fill, identifies likely contributors to the accelerated erosion rates, and makes recommendations regarding concepts of mitigating the erosional hot spot. The second report extends the conceptual recommendations of this report by developing and analyzing shore-protection alternatives and estimating required stone sizes and volumes for the recommended alternatives.

Beach-Fill Summary

The Atlantic Coast of New Jersey-Sandy Hook to Barnegat Inlet Beach Erosion Control Project (New York District 1989) was designed in three sections (Figure 1), Section 1 being Sea Bright to Ocean Township, New Jersey. Section 1 is scheduled to be constructed in four contracts (Figure 2), with the first contract, Contract 1A, ranging from the southern boundary of Monmouth Beach north to Rumson Bridge (3.1 miles[1] in length). The planform design for the Contract 1A beach fill begins with sta 131 near Rumson Bridge and extends south to sta 295 near the Monmouth Beach/Long Branch municipal boundary (Figure 3). Beach-fill placement for Contract 1A began in June 1994 and ended for the season on 3 January 1995 resulting in completion of the southern third of the contract. Construction of Contract 1A resumed in April 1995, proceeding northward to completion in November 1995. By late 1995, a 0.5-mile length of beach fill (between sta 253 and 277) in the southernmost portion of Contract 1A was suffering from accelerated erosion, with erosion rates decreasing between

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page viii.

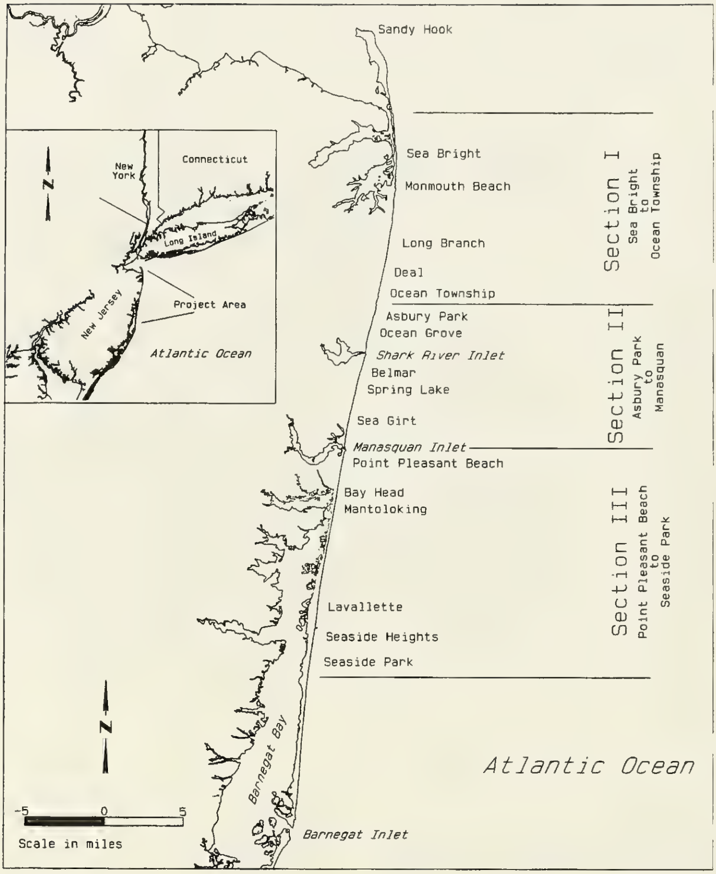

Figure 1. Atlantic Coast of New Jersey Beach Erosion Control Project

sta 277 and the southern boundary of Contract 1A. This hot spot was renourished during November 1995 with an additional placement of 230,000 cu yd of beach-fill material.

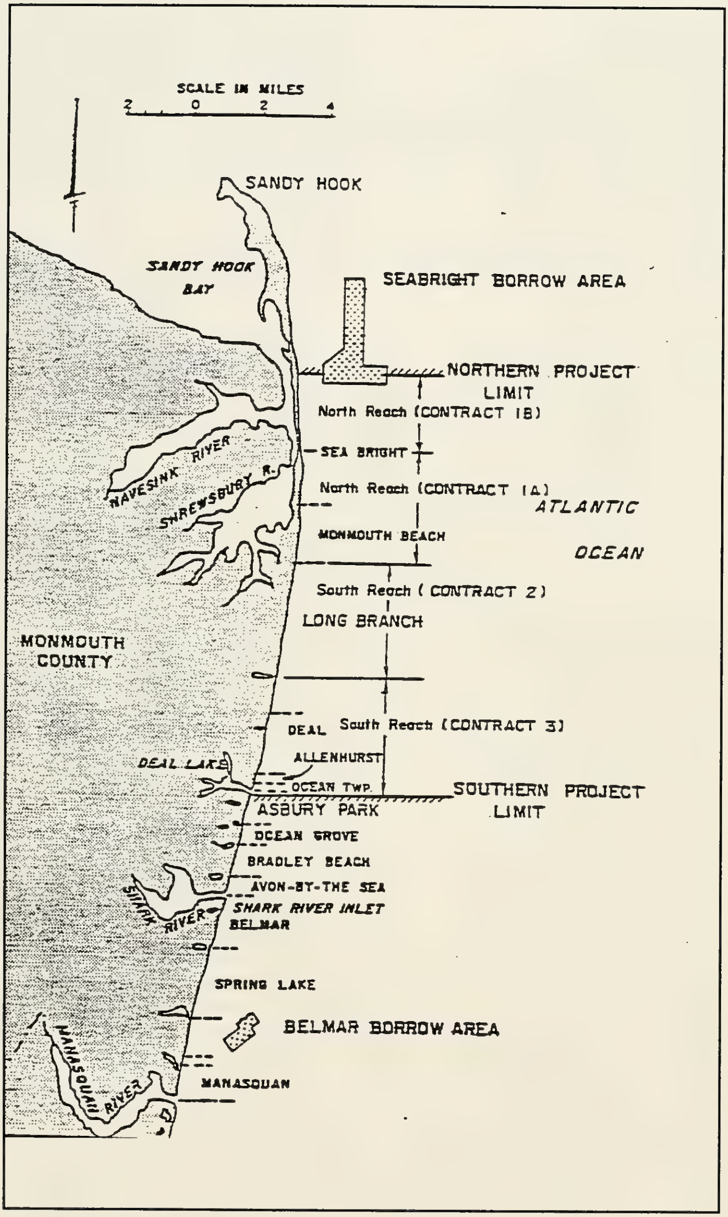

Figure 2. Section I - Sea Bright to Ocean Township, NJ (New York District 1989)

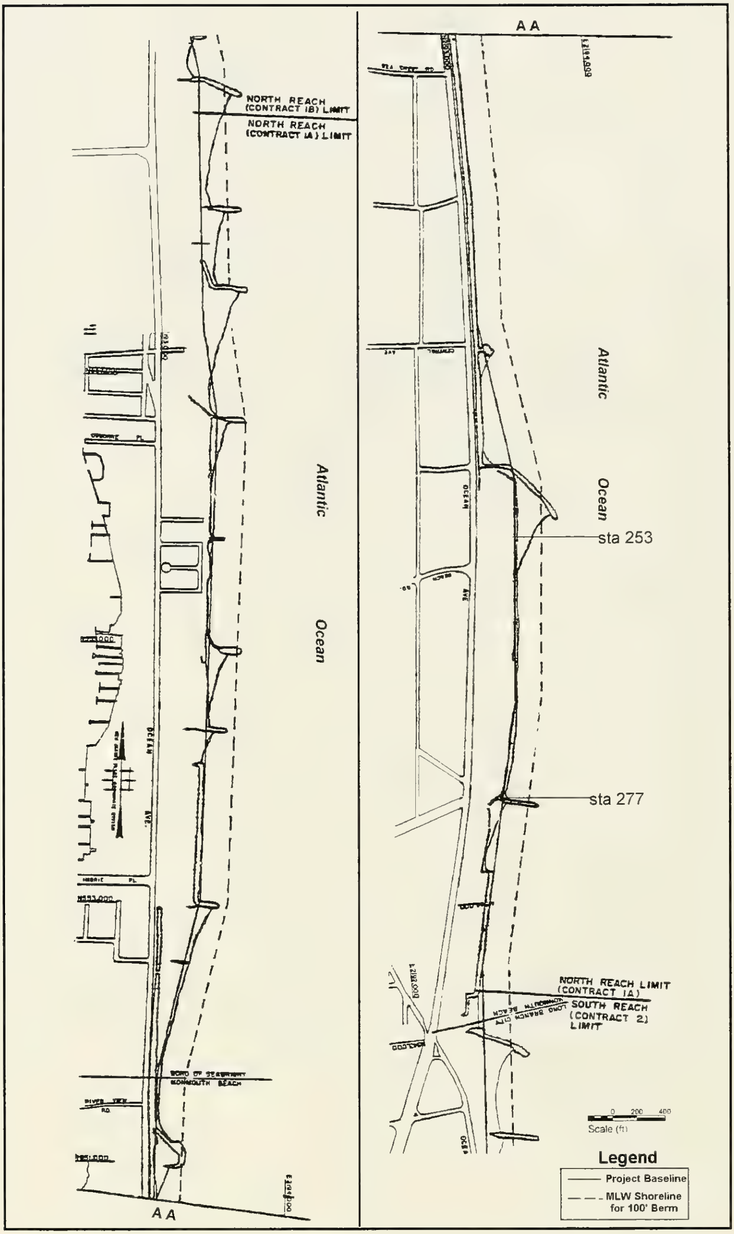

Figure 3. Beach-fill planform design (New York District 1989)

Beach-Fill Specifications

The beach fill within Contract 1A has a design berm width of 100 ft, a design berm elevation of 10 ft mean high water, and a berm cap of 2 ft. The mean low water shoreline for the 100-ft design berm is presented by the dashed line in Figure 3. The stationing labels presented in this figure are used later to reference specific positions along the beach fill and as identifiers for beach profile surveys. The construction template has a 1V:15H slope from the berm to mean low water. Below mean low water, the construction template slope decreases to 1V:20H as shown in Figure 4.

Scope of Study

Four hypotheses have been developed as potential causes of the hot spot found within Contract 1A: wave focusing by Shrewsbury Rocks, cross-shore adjustment, beach-fill end losses, and beach-fill planform adjustment. These hypotheses will be further examined in this report to determine the contributing factors of the accelerated erosion at the hot spot.

Wave focusing by Shrewsbury Rocks

Shrewsbury Rocks is a rock outcropping located approximately 1.2 miles northeast of the hot spot at Monmouth Beach, New Jersey. It is hypothesized

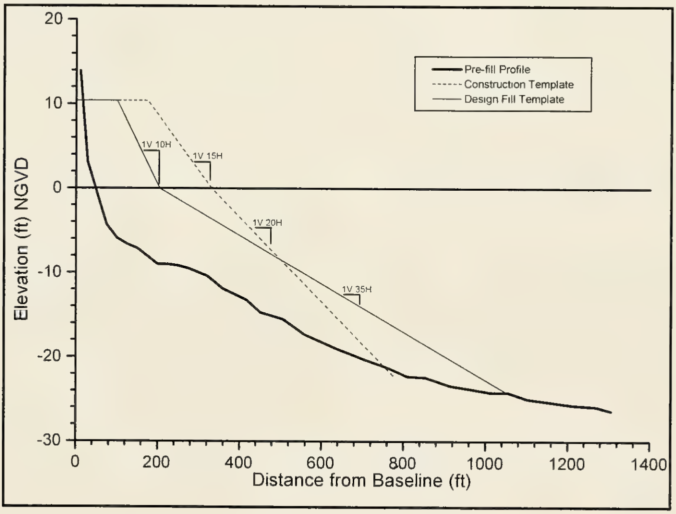

Figure 4. Design and construction template (New York District 1989)

that wave focusing by Shrewsbury Rocks may cause gradients in wave height and direction which in turn produce gradients in longshore sediment transport. Gradients in longshore sediment transport rates could then cause erosion of the shoreline. This task evaluates the potential of wave focusing by Shrewsbury Rocks to cause the Monmouth Beach hot spot. Evaluation of the offshore feature's influence on the hot spot includes statistical analysis of available wave gauge information and determination of the reaches of shoreline within the shadow zone of the rock outcropping.

Cross-shore adjustment

Erosion within the hot-spot region may be due to greater than anticipated cross-shore adjustment of the construction template, resulting in decreased beach width at the hot spot. In evaluating the contribution of cross-shore profile adjustment to the development of the hot spot, an analysis of the cross-shore evolution of the beach-fill cross section is performed. The prefill, postfill, and theoretical equilibrium profile shapes are compared and an assessment made of the present state of cross-shore adjustment and the anticipation of additional cross-shore adjustment of the profiles and subsequent decreases in beach width.

Beach-fill end losses

End losses are significant for beach fills constructed with short lengths. Since the beach fill in the hot-spot region at southern Monmouth Beach protrudes seaward of the beach fill placed in adjacent areas, it can be ideally treated as a short, rectangular beach fill placed upon a longer beach fill. This task examines the losses associated with a short, rectangular fill using an analytical approach and an idealized application of the GENESIS numerical model for shoreline change (Hanson and Kraus 1989).

Beach-fill planform adjustments

Because the beach fill in the hot-spot area at Monmouth Beach protrudes seaward of the adjacent shorelines, the loss of beach fill from the hot-spot region may be related to the planform adjustment of the beach fill to an orientation similar to the offshore bathymetric contours. This task focuses on identifying trends in bathymetric evolution of the beach fill and the implications of these evolutionary trends in the development of the erosional hot spot.

Primary Objective

The objective of this study is to evaluate coastal processes at the hot spot and identify processes that appear to contribute to the accelerated erosion rates of the beach fill. Following evaluation of the four proposed hypotheses, the major contributing factor(s) for the development of the erosional hot spot are identified. In addition, conceptual design alternatives or construction procedures are recommended for further consideration and study.

2 Wave Focusing by Shrewsbury Rocks

This analysis examines the potential that the hot spot at Monmouth Beach is caused by differential longshore sand transport rates caused by wave transformation over the Shrewsbury Rocks. Hot-spot erosion at Corps of Engineers beachfill projects at Ocean City, Maryland, and Folly Beach, South Carolina, has been linked to differential longshore sand transport caused by irregularities in the nearshore bathymetry. Consequently, there is a possibility that wave transformation over the Shrewsbury Rocks could be responsible for the observed hot spot at Monmouth Beach. This chapter examines the available wave data and determines what areas of the beach are down-wave of the rock outcropping under wave conditions observed since construction of Contract 1A.

Wave Statistics

Wave data for the project region are available from two gauges. The gauge nearest the beach fill is located at Long Branch, New Jersey (40.30° N, 73.97° W), in a water depth of approximately 32.8 ft (10 m). A slope array was deployed at Long Branch in 1994 and replaced with a directional wave gauge (DWG) in 1995. Wave data are available from January 1994 - March 1996. These data were collected at a rate of 1 Hz for 1,024 sec. Samples were collected each hour during expected storm conditions and once every 4 hr for low-wave-height conditions. Wave periods and directions were not recorded for wave heights less than 0.7 ft (0.2 m). Numerous gaps appear in the wave record (30 percent of the gauge deployment). The longest gap was mid-November 1994 to mid-July 1995, when the slope array failed and was replaced with the DWG. Wave directions are also missing from January to mid-March 1994. Statistics from the Long Branch gauge are given in Appendix A1. The statistics include breakdowns of the wave height, period, and direction by month; wave height and period by direction; and the mean and maximum wave heights for the duration of the gauge deployment. Statistical tables and mean heights were generated using data taken at 4-hr increments (0, 400, 800, 1200, 1600, 2000 Greenwich mean time (GMT)) to evenly weight storm and nonstorm conditions in the statistics. The statistical values have not been adjusted to account for the nonrandom gaps in the data. The maximum recorded wave height was 13.8 ft (4.2 m) on

11 November 1995. The mean wave height ranged from 2.7 ft (0.82 m) in January to 1.9 ft (0.58 m) in June. Figure 5 is a wave rose for the Long Branch gauge, showing the percent occurrence of wave conditions in sixteen 22.5-deg direction bands. The percent occurrences in the wave rose have been adjusted, by month, to reflect an even distribution of wave conditions throughout the year accounting for gaps in the record. The adjustment is made by calculating the distribution for each month, and then weighting the data for each month based on the number of days in the month.

Wave data are also available from the National Data Buoy Center (NDBC) Buoy 44025, located south of Long Island at 40.25° N, 73.17° W. The buoy is located almost directly offshore of Monmouth Beach in a water depth of 130 ft (40 m). Wave data are available from January 1994 - February 1996. Data were collected at a rate of 1 Hz for 1,024 sec, once per hour. The buoy data were examined because the record is more complete (93-percent data return as compared with Long Branch gauge's 70 percent). The only significant gap in the data record was 11 November to 4 December 1995 (note that this is the time of the maximum wave height at the Long Branch gauge). Statistics from the buoy are given in Appendix A2. The maximum recorded wave height was 24.3 ft (7.4 m) on 3 March 1996 (wave height at the Long Branch gauge was 13 ft (4 m) at that time). The wave heights at the buoy are significantly larger than measured at Long Branch. The distribution of wave periods above 10 sec is similar for the two gauges, but the buoy records more short-period wave events (periods less than 7 sec) because of local wave generation between the New Jersey coast and the buoy location. Wave directions are more broadly distributed at the buoy than at Long Branch because of the deeper water depth and longer fetch from the west. Both the buoy and Long Branch gauge have peaks in the directional distribution at 112.5-135 deg (angles are referenced clockwise from North). The buoy also has a secondary peak at 292.5 deg. Figure 6 is a wave rose for the Long Island buoy. The percent occurrences have been adjusted to account for gaps in the record. Wind speeds and directions measured at the buoy are included in the statistics given in Appendix A2. Figure 7 is a wind rose for the buoy site.

Although there are large gaps in the Long Branch data record, these data are used to look at the wave directions at Monmouth Beach for assessing the wave focusing by Shrewsbury Rocks. The proximity of the Long Branch gauge to Monmouth Beach makes it most relevant for evaluating the local wave climate, in spite of data gaps.

Figures 8-11 show seasonal wave roses for the Long Branch measurements. Note that the percentages in each plot add to 100 percent. Two dominant patterns arise. In the fall and winter (September through February), the dominant wave direction is 112.5 deg (east-southeast) (40 percent). The percent occurrence in the adjoining bands (90 and 135 deg) is 17-24 percent and 27-28 percent, respectively.

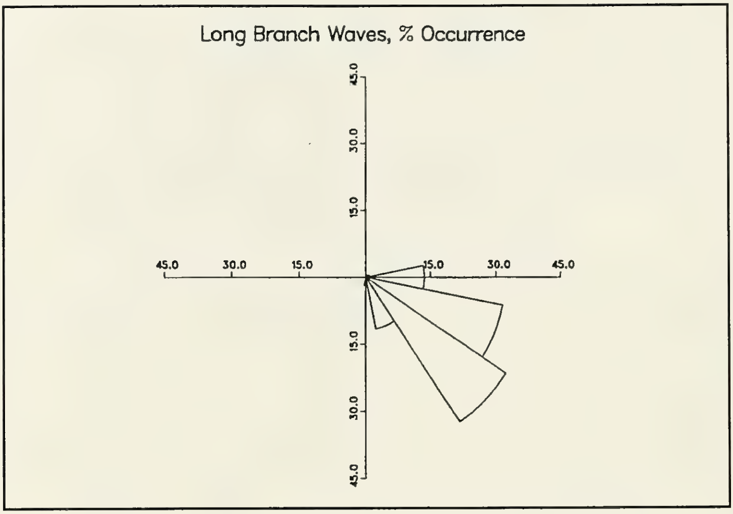

Figure 5. Long Branch wave rose

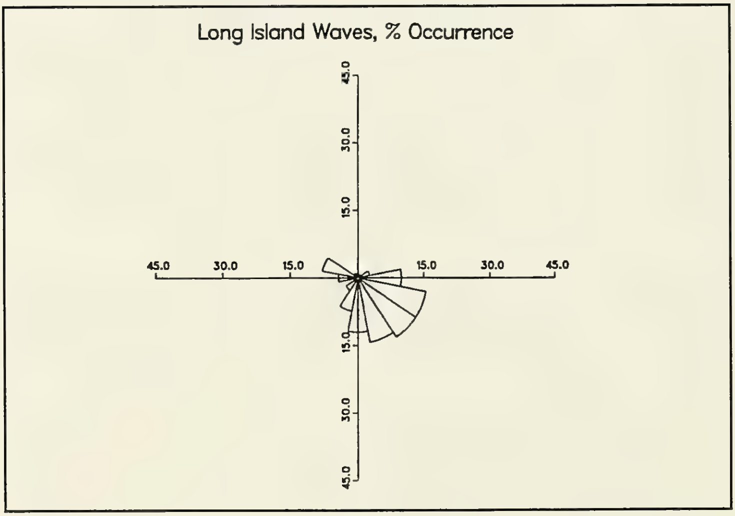

Figure 6. Long Island buoy wave rose

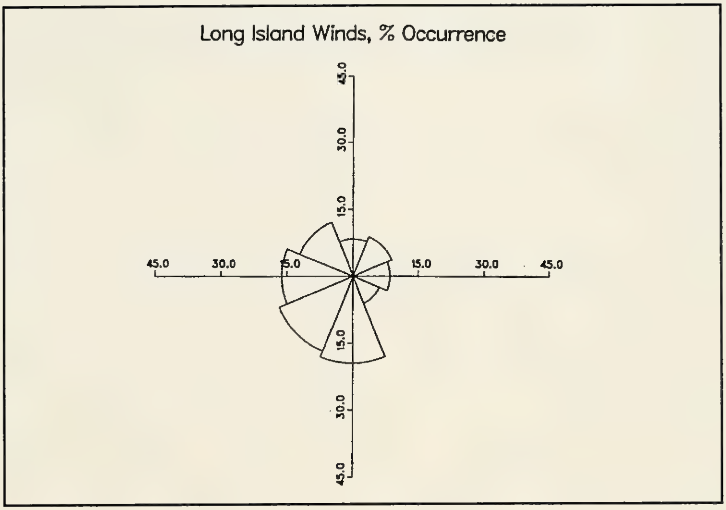

Figure 7. Long Island buoy wind rose

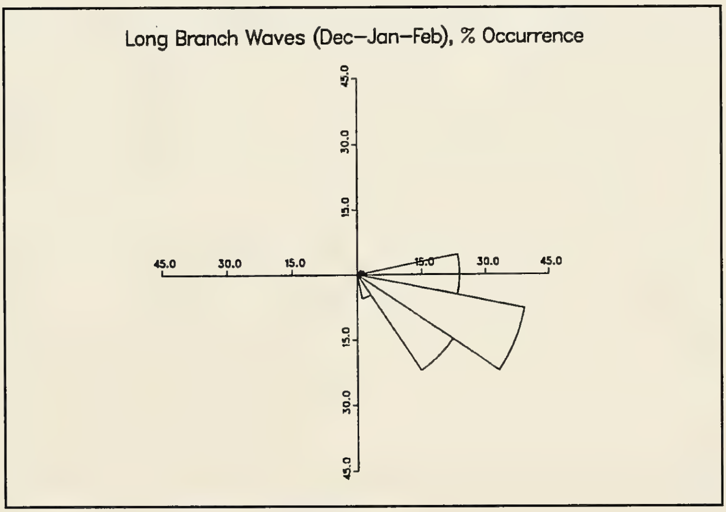

Figure 8. Long Branch wave rose (winter)

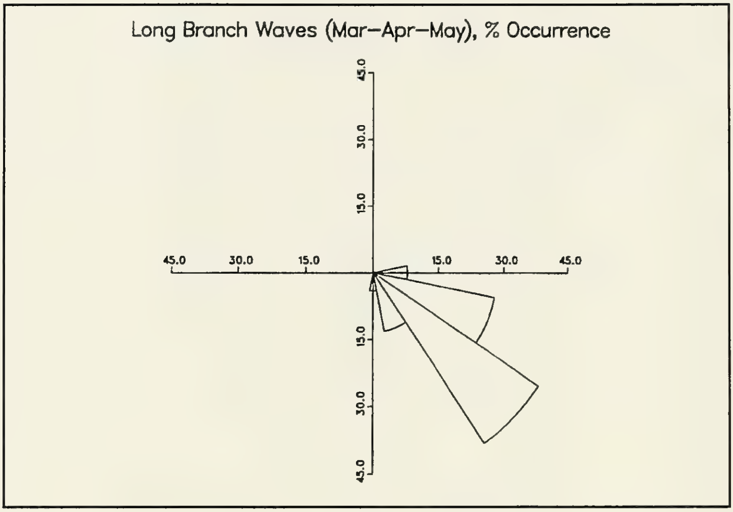

Figure 9. Long Branch wave rose (spring)

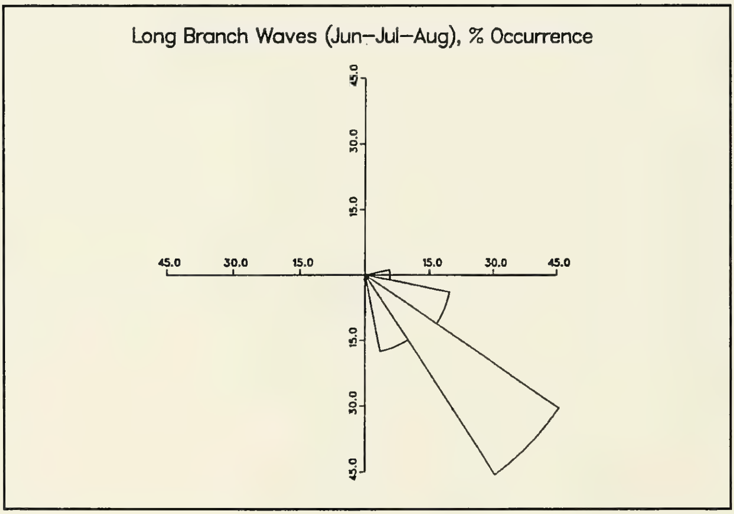

Figure 10. Long Branch wave rose (summer)

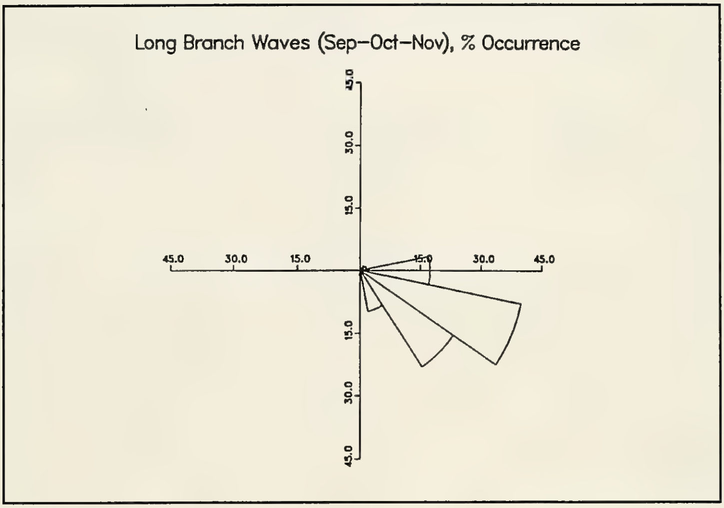

Figure 11. Long Branch wave rose (fall)

In the spring and summer, the dominant wave direction is 135 deg (southeast) (46-55 percent). The adjoining bands (112.5 and 157.5 deg) account for 20-28 percent and 13-18 percent, respectively. Occurrences of wave directions outside the range 78.8 to 168.7 deg are rare. Angles north of this range are sheltered by Long Island, and local wave generation is limited by the short fetch. Angles south of the range are nearly parallel to shore and thus would have refracted to less oblique angles seaward of the 33-ft (10-m) depth, unless the wave periods were very short. The east-southeast and southeast dominant wave directions are consistent with the northerly direction of net longshore sand transport at Monmouth Beach. Figures 12 and 13 present histograms of the wave height and period distributions for all populated wave directions. The histograms again show that the dominant wave directions are in the 112.5- and 135-deg bands. The distributions of wave heights less than 3.3 ft (1.0 m) are fairly flat, with a large drop off in heights above 3.3 ft (1.0 m). The 90-deg band has a relatively flat distribution of heights and periods. The direction bands 22.5, 45.0, 67.5, and 180.0 deg contain only short-period and low-wave-height events.

The incident wave directions illustrated in the statistical tables and figures show that the wave climate at Monmouth Beach is dominated by waves from the southeast (39 percent) and east-southeast (32 percent). Fourteen percent of the waves approach from the east, but less than 2 percent total from directions north of east, and these are short-period, small-height waves.

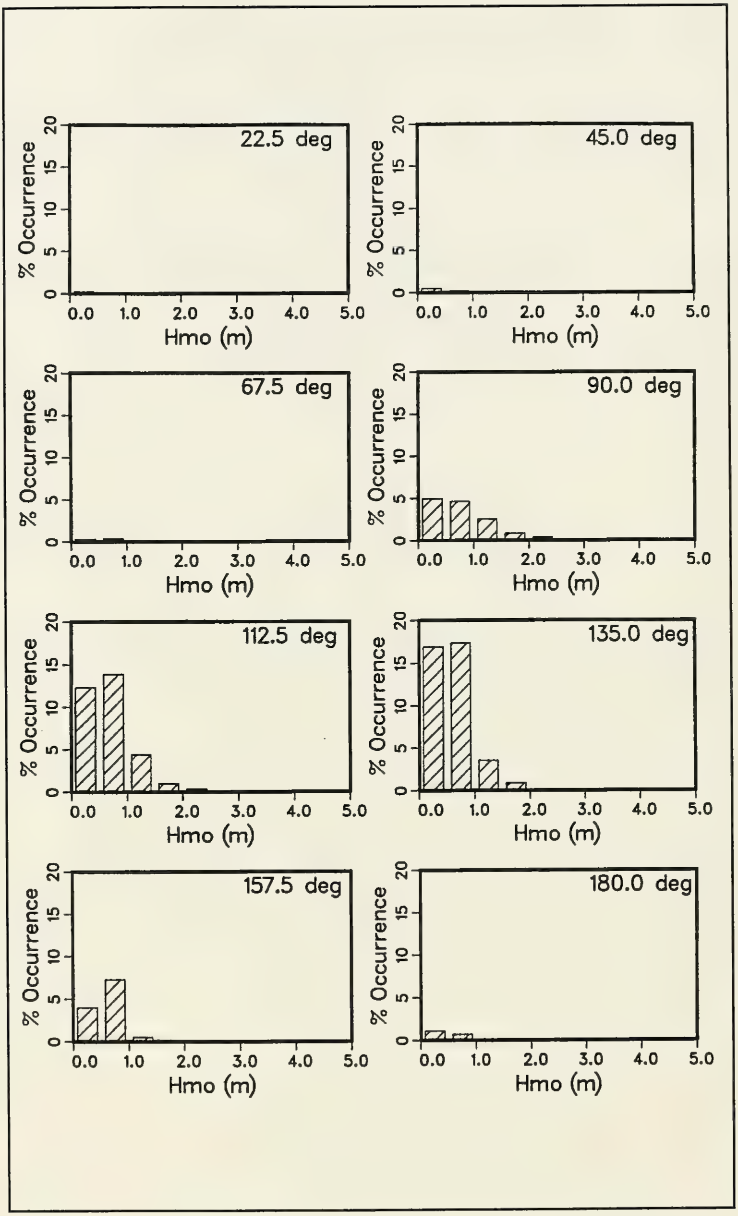

Figure 12. Histograms of wave-height distribution by direction (Long Branch gauge)

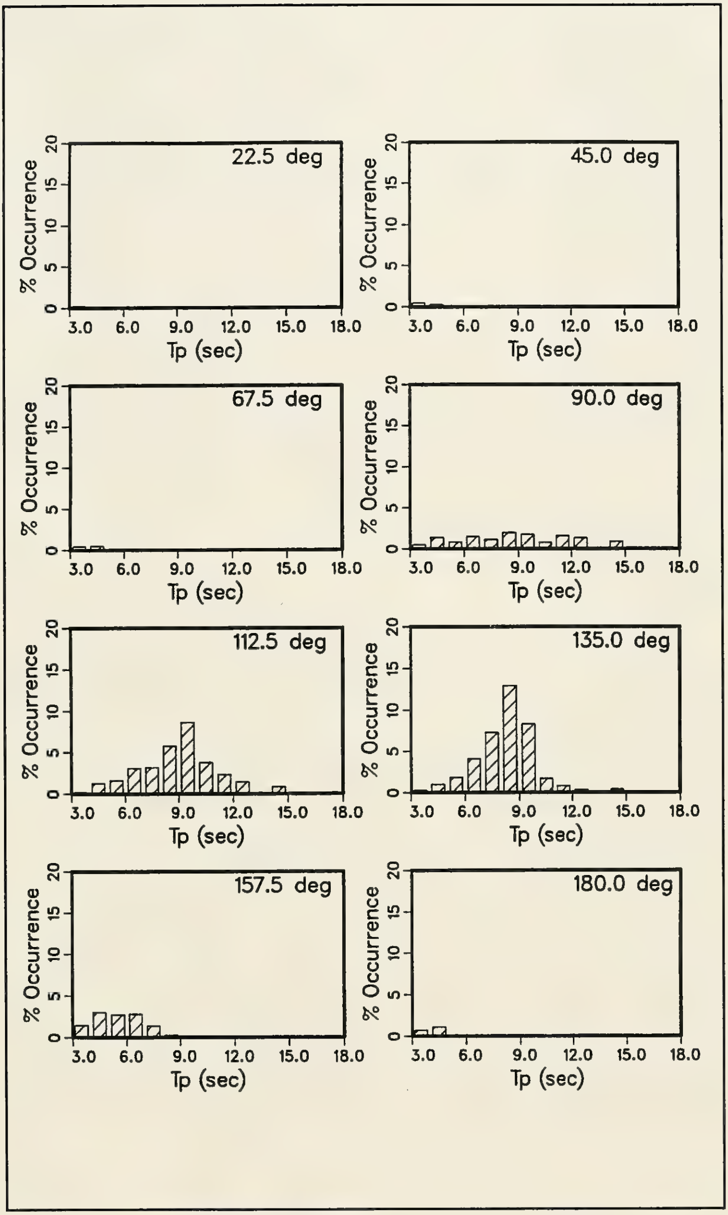

Figure 13. Histograms of wave-period distribution by direction (Long Branch gauge)

The hot spot at Monmouth Beach is approximately 0.7 miles south of Shrewsbury Rocks. Impacts of the rocks on the beach-fill project are expected directly inshore from the rocks or to the north, not to the south. The expected impact could include increased wave height and a local reversal in wave direction, producing gradients in longshore sand transport. A previous study of coastal processes in the region (Kraus et al. 1988) showed one example of wave height and angle variation along the shore from the wave transformation model RCPWAVE (Figure 14 reproduces Figure 11 from Kraus et al.). Figure 14 shows, for an incident wave angle of 101.5 deg (-7.5 deg in wave model), the wave amplification at Cell 142 is 1.7. Cell 142 is approximately directly west of Shrewsbury Rocks, near sta 218. More southerly wave directions would move the location of the wave focusing further north of the rocks.

The bathymetry contours just south of Shrewsbury Rocks angle offshore toward the rocks. This bathymetry feature could increase the breaking wave angles on the northern portion of the hot spot and contribute to a local increase in northerly sand transport. It is interesting to note that the indentation in the shoreline to the north of the hot-spot region is located in the lee of Shrewsbury Rocks. Accelerated erosion of the recently completed beach fill in the lee of Shrewsbury Rocks (centered around sta 218) may be a future concern.

Storms

Nineteen storms with maximum wave heights exceeding 6.6 ft (2 m) were measured at the Long Branch directional wave gauge during the 27 months of data collection (approximately 19 months, excluding gauge downtime). Storm peaks are denoted as the time when the maximum wave height occurred. Table 1 summarizes peak wave conditions for each storm. The peak period and direction are the period and direction associated with the maximum wave height. Storm duration is the approximate length of time when the wave height exceeded 6.6 ft (2 m). Wave conditions exceeding 6.6 ft (2 m), sorted by storm magnitude, are listed in Appendix A3. The period of record at the Long Branch gauge is not sufficient to characterize the storm climatology, but does give examples of typical, short-return-period storm conditions. The range of peak directions for wave heights exceeding 6.6 ft (2 m) is 86 to 140 deg, with a mean direction of 109 deg. The storm wave conditions imply predominant storm transport to the north in Contract 1A. Focusing of wave energy by Shrewsbury Rocks would be manifested as a hot spot in the middle or northern half of Contract 1A (near sta 218), not the southern end. Storm wave directions are approximately shore normal (100 deg) or well south of shore normal (130 deg). Waves in the northeast quadrant are fetch limited, because of the presence of Long Island, and wave heights are limited to approximately 1.6 ft (0.5 m).

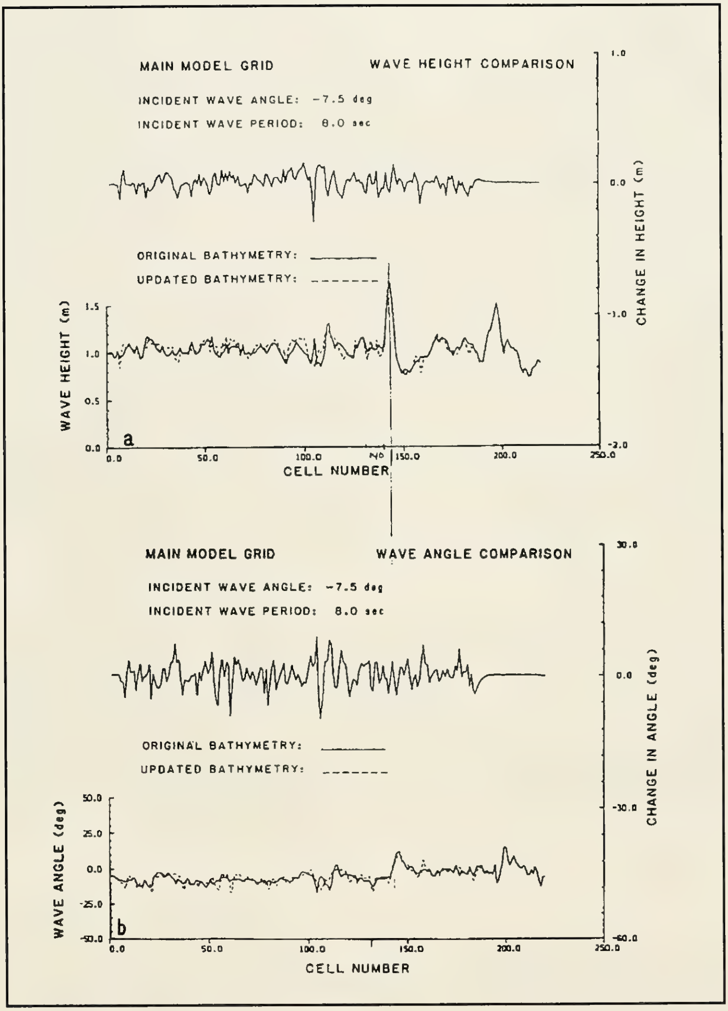

Figure 14. Wave height and angle variation near Monmouth Beach, NJ (from Kraus et al. 1988)

Table 1
Peak Storm Conditions at Long Branch

H_{mo}, m	T_p, sec	θ_p, deg	Duration, hr	Date
4.22	10.7	101	19	95111501
4.08	9.8	129	10	95111205
4.07	11.6	---[1]	34	94030309
3.90	11.6	108	28	96010811
3.79	9.8	---	21	94010415
3.76	8.5	97	11	96032003
3.55	8.5	107	18	94092304
3.14	8.5	---	19	94022322
3.14	9.1	130	10	96011920
3.05	9.1	133	12	96012721
2.46	7.5	86	11	95122002
2.38	6.7	96	5	96011221
2.36	8.0	121	28	94111723
2.33	7.1	96	9	96032912
2.23	8.5	---	10	94021123
2.17	7.1	102	6	96010308
2.11	7.1	---	9	94012612
2.11	9.1	---	3	94012823
2.06	7.5	105	4	94101512

[1] No direction information available.

Summary

Waves at Monmouth Beach typically approach from 90 to 157.5 deg, with a dominant direction of 135 deg. Less than 2 percent of the waves approach from north of east. These waves are fetch limited and have small heights (>1.6 ft (0.5 m)) and short periods (>5 sec). The dominant southeast and east wave directions shown in the wave statistics and the storm data indicate that wave focusing by Shrewsbury Rocks would impact the mid to north end of Contract 1A and not be a factor in the hot spot located at the south end of the project. Wave focusing would be manifest as a local amplification in wave height and local reversal or gradient in wave direction. The northeasterly angle of the bathymetry contours between the hot spot and Shrewsbury Rocks could increase the breaking wave angles on the northern portion of the hot spot and contribute to a local increase in northerly sand transport.

3 Beach Profile Evolution

Beach-fill material placed along a shoreline is typically constructed in the form of a simple, predefined template in which the design berm elevation is extended some distance seaward of the prescribed berm width. Side slopes of the construction template are considerably steeper than the natural profile. This construction practice allows easier placement of the beach-fill material and facilitates the estimation of placed volume during construction. Adjustment of this oversteepened construction template towards an equilibrium beach profile is anticipated in the design of beach fills. Transport of material from the upper portions of the beach-fill construction template to the offshore portions of the beach profile is accomplished through cross-shore transport processes.

Hypothesizing that cross-shore processes could produce greater than anticipated profile adjustment, the accelerated retreat of the shoreline at the Monmouth Beach hot spot could be attributed to beach-fill sediments moving offshore along the beach profile. As part of this study, the available profile survey data are evaluated to determine if cross-shore transport is a significant contributing factor to the shoreline erosion at the hot spot. In addition, the equilibrium profiles for several locations alongshore are computed and compared with the most recent beach profile surveys to determine whether additional cross-shore adjustment should be anticipated, further reducing the beach width in the vicinity of the hot spot.

Profile Survey Data

Data used in the beach profile analysis were collected to compute beach-fill pay quantities. These data were collected at various stages of completion of the project (between June 1994 and October 1995) at 100-ft, alongshore intervals over the particular reach of the project being surveyed. The profile surveys typically extend from the seawall or revetment approximately 1,000 ft seaward with depths ranging from 20-25 ft in the National Geodetic Vertical Datum (NGVD).

Beach Profile Evolution

Beach profiles are compared over the period June 1994 to October 1995 to examine beach profile evolution. The alongshore locations indicated in Figure 15 were selected for evaluating the beach profile evolution within and south of the identified hot-spot region (sta 255, 265 ,275, 286, and 290) as well as immediately north of the hot spot (sta 208, 224, 232, 240, and 245). These profiles are used to evaluate beach profile evolution and associated cross-shore and longshore processes present at each location.

Hot-spot region

Within and south of the hot-spot region, beach profile evolutions of sta 255, 265, 275, 286, and 290 are examined. Available beach profile surveys at each location are used to discuss the sediment transport processes that contribute to the evolution of each profile.

Station 255 is located near the tip of Groin 44 (New York District 1989), a curved groin approximately 4,500 ft (0.85 mile) north of the southern boundary of Monmouth Beach. Figure 16 presents the profile surveys for sta 255 from June 1994 to October 1995. The evolution of the beach profile at sta 255 indicates that the groin impounded northbound beach-fill material placed to the south of sta 255 prior to construction of the design template in October 1994. After placement of beach-fill material in October 1994, the beach profile at sta 255 remains relatively stable with only a slight shoreward transition of the profile and little cross-shore profile adjustment. It is likely that the stability of this profile is due to its proximity to Groin 44.

Station 265 is located within the area considered the Monmouth Beach hot spot. The beach profile surveys shown in Figure 17 indicate dynamic changes over time at this location. Placement of the construction template is apparent in the October 1994 beach profile. After October 1994, progressive erosion of the profile is evident. The beach profile at sta 265 lost 156 cu yd/ft between October 1994 and October 1995. The net losses of material from the beach profiles at this location and lack of evidence that material is moving offshore indicate that longshore sediment transport is dominant at this location.

The beach profiles at sta 275 (Figure 18) indicate placement of the construction template between August and September of 1994, then progressive erosion of the profile until its condition approaches the prefill condition in October 1995. Similar to sta 265, the profile at sta 275 does not indicate any cross-shore profile adjustment; instead, there is a net loss of 170 cu yd/ft of beach fill between September 1994 and October 1995.

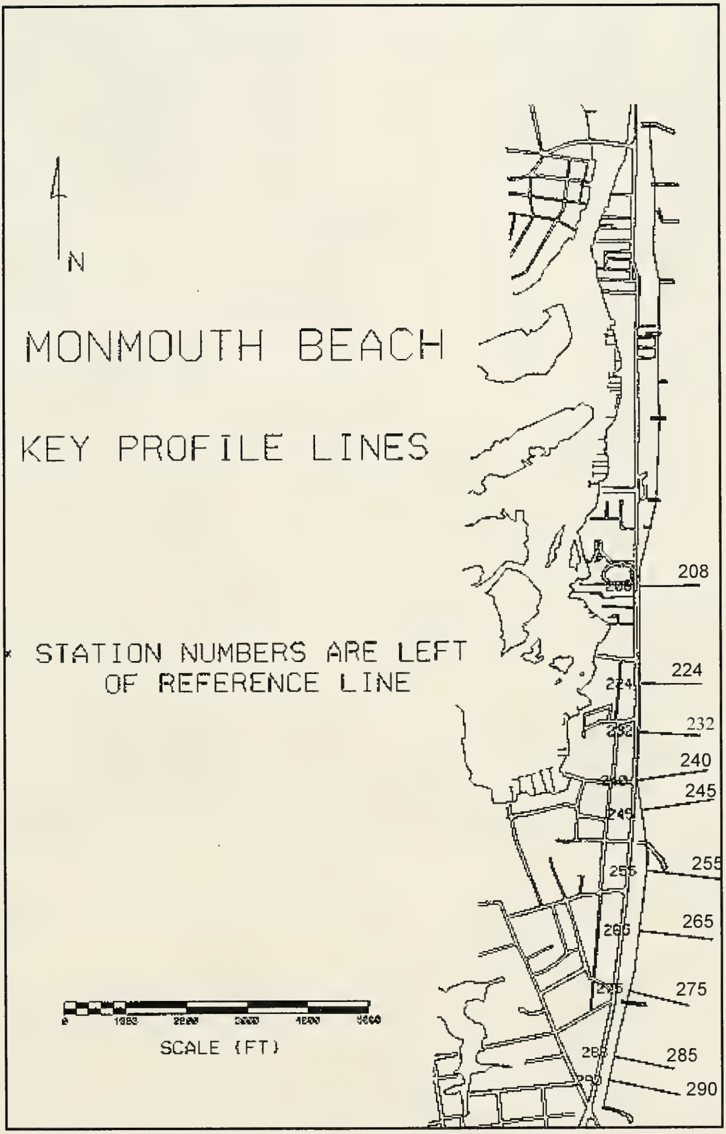

Figure 15. Beach profiles used in cross-shore analysis

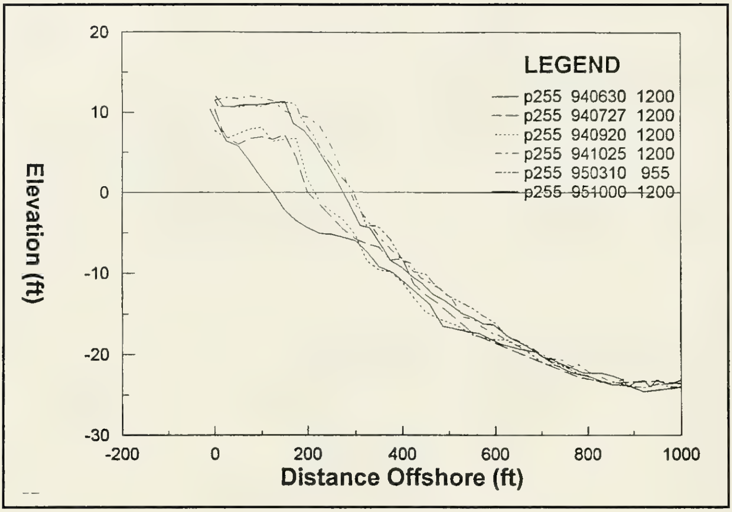

Figure 16. Beach profile evolution at sta 255

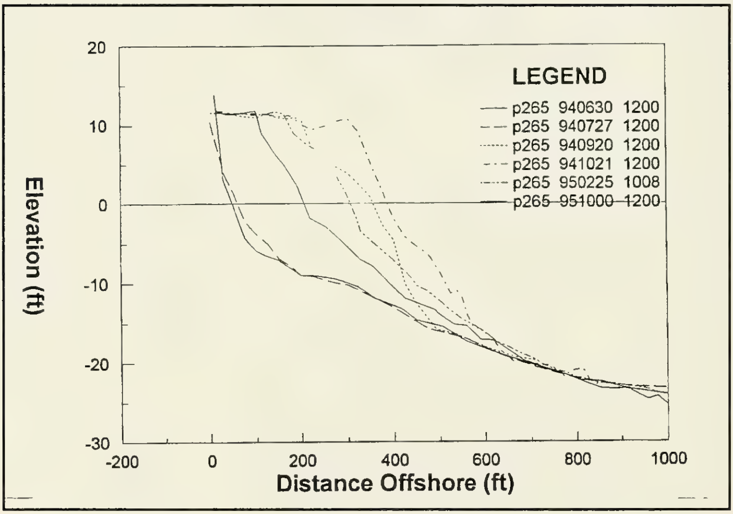

Figure 17. Beach profile evolution at sta 265

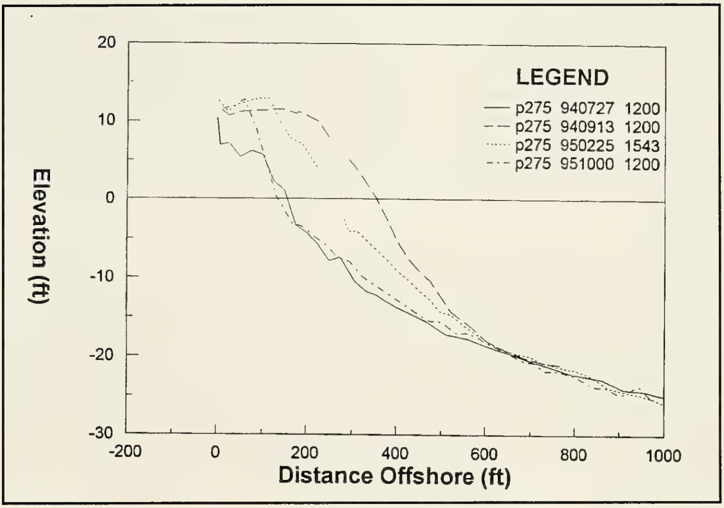

Figure 18. Beach profile evolution at sta 275

Beach profiles at sta 286, 290, and 294 indicate similar patterns of evolution as sta 265 and 275, but have net sediment losses of 70, 36, and 36 cu yd/ft, respectively (significantly smaller than the losses at sta 265 and 275). These profiles are given in Appendix B.

A consistent pattern within the general region of the hot spot is significant losses of material from the beach profiles with little or no cross-shore profile adjustment. This indicates that the loss of material from the hot-spot region is related to longshore transport processes instead of cross-shore transport processes.

North of hot spot

No beach-fill construction was completed north of the hot-spot region before beach-fill placement ended for the season on 3 January 1995. Beach-fill construction at this time advanced only as far north as the base of Coastal Structure 44.[1] Before construction resumed in April 1995, all stations along the beach-fill reference line were surveyed. The March 1995 profile surveys north of Groin 44 reveal that a large volume of material accumulated between December 1994 and March 1995. This indicates that a significant amount of material lost from the hot-spot region was transported north and deposited in the adjacent region to the north. Profiles 208, 232, 240, and 245 are presented to demonstrate the effect of the evident longshore transport.

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[1] Personal Communication, 12 August 1996, Brian Carr, New York District.

Profiles 245 and 240 are located 400 and 900 ft north of the base of Coastal Structure 44, respectively. These two profiles are located immediately downdrift of the beach fill completed on 3 January 1995. Profile 245 (Figure 19) gained 64 cu yd/ft between December 1994 and March 1995, a period during which there was no beach-fill activity. Similarly, beach profiles at sta 240 (Figure 20) indicate that a unit volume of 69 cu yd/ft was gained during November 1994 and a unit volume of 109 cu yd/ft was gained between December 1994 and March 1995.

Further north, at sta 208 and 232, beach profiles exhibit trends similar to sta 240 and 245. Beach profiles at sta 232 (Figure 21) indicate a unit volume increase of 31 cu yd/ft during November 1994 and a unit volume increase of 60 cu yd/ft between December 1994 and March 1995. The beach profiles at sta 208, one of the stations furthest north of the hot spot that was surveyed prior to the March 1995 survey, indicate a unit volume gain of 69 cu yd/ft between October 1994 and March 1995 (Figure 22). Because of the lack of December 1994 survey data north of sta 206, the northern extent of material transported from the hot-spot area is unknown. However, significant gains of material on the profiles north of the hot-spot area between October 1994 and March 1995 indicate that large volumes of beach-fill material were transported north from the hot-spot region to the profiles experiencing significant gains in unit volume.

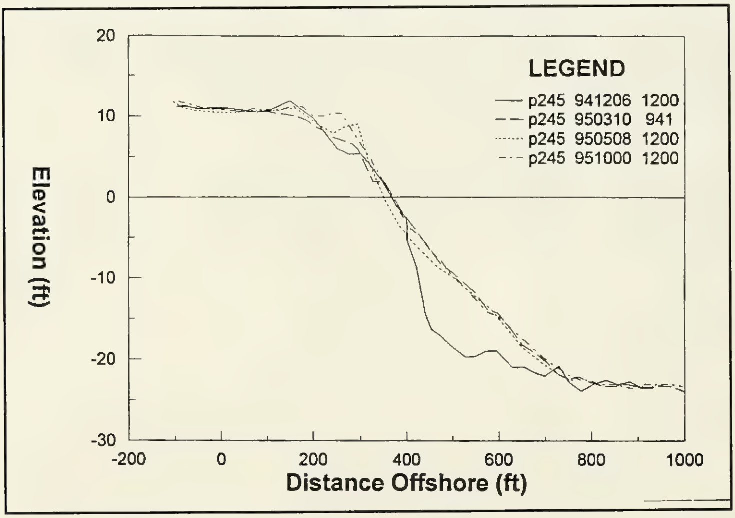

Figure 19. Beach profile evolution at sta 245

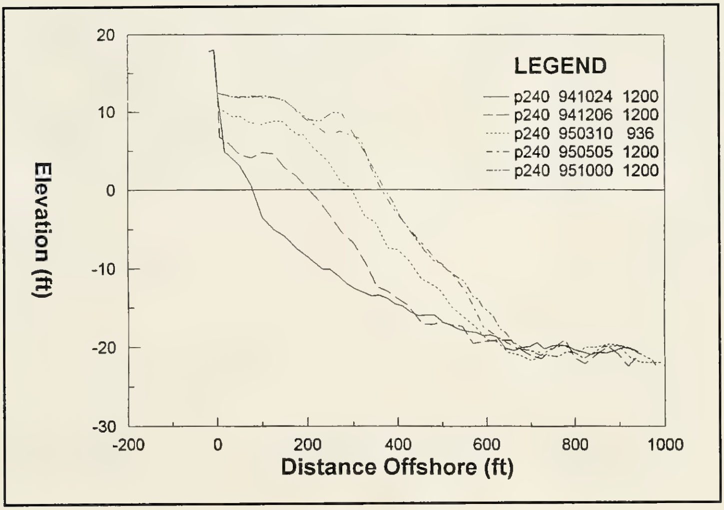

Figure 20. Beach profile evolution at sta 240

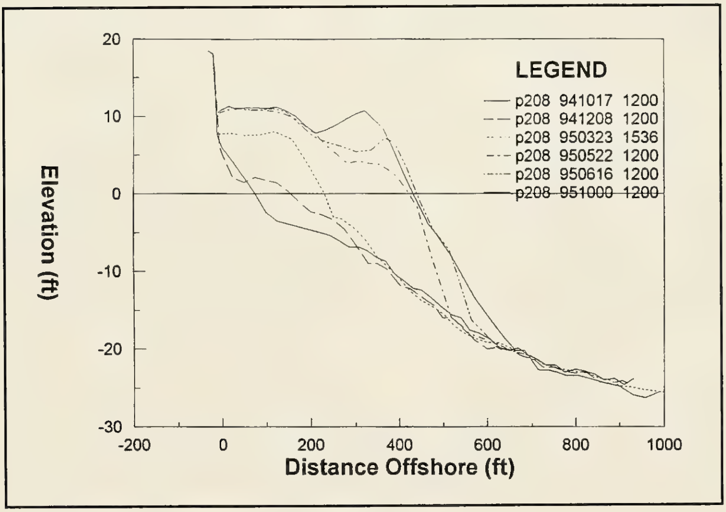

Figure 21. Beach profile evolution at sta 232

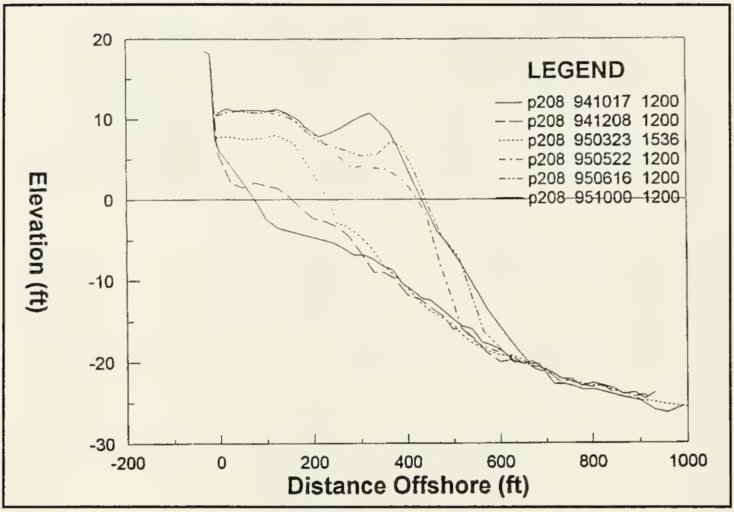

Figure 22. Beach profile evolution at sta 208

Beach Profile Equilibrium

The shape of the beach profiles at the hot spot in comparison with the equilibrium profile is useful in assessing whether additional cross-shore adjustment and consequential shoreline retreat will occur. Dean (1977, 1991) has demonstrated that an equilibrium profile relationship, $y = Ax^{2/3}$, can be used to estimate the equilibrium beach profile shape, where y is water depth and x is distance seaward of the shoreline. The empirical shape factor, A, has been shown to be related to the median sediment diameter, d_{50} (Moore 1982). Using the equilibrium profile relationship and available sediment grain-size distributions, an assessment of the beach profile's approach to cross-shore equilibrium is made.

Sediment characteristics

The median grain size diameter of the beach fill was quantified to specify an equilibrium beach profile. Sediment samples were collected between October 1994 and January 1995. Four sediment samples were collected at 200-ft alongshore intervals between sta 246 and 276 with sampling locations at the backshore beach, midberm, mean high water, and mean low water. The analysis of the sand samples indicates that grain sizes across the beach fill poorly sorted (with exception of the mean low water samples), as expected for a newly placed beach fill that has not been subjected to much wave activity.

A composite analysis of all sediment samples collected between sta 246 and 276 resulted in a ϕ_{50} of 0.65 (d_{50} = 0.64 mm) and a standard deviation of 0.77ϕ. If the typical lognormal grain-size distribution of sediments is assumed for the beach-fill material, a 95-percent confidence interval for the ϕ_{50} is defined by the range of ϕ units within two standard deviations of the mean. For the samples taken from the beach fill, the range of ϕ_{50} defining the 95-percent confidence interval is 2.20 to -0.89, which corresponds to a range from d_{50} of 0.22 to 1.86 mm. The sieve analysis is presented in Appendix B.

Profile comparisons

Based upon the statistical definitions from the sieve analysis, equilibrium profiles computed from the median grain size and the bounds of the 95-percent confidence interval were compared with the October 1995 profiles. The comparisons of the measured profiles with the equilibrium profiles give an indication of each profile's equilibrium status. Profiles on the steep side of the mean equilibrium profile are expected to adjust in the cross shore to come closer to equilibrium. Beach profiles that are near equilibrium are not to be expected to adjust substantially in the cross-shore direction.

In the region between sta 255 and 295, beach profiles are near their equilibrium shape. Figure 23 shows the beach profile at sta 275 with the corresponding equilibrium profiles for median grain diameters of 0.22, 0.64, and 1.86 mm. It is evident in this figure that the beach profile at sta 275 is in a similar shape as the equilibrium beach profile for the average d_{50} from the sieve analysis. Significant shoreline recession because of cross-shore adjustment of this profile is not expected.

In contrast to the profiles of the hot-spot region, the beach profiles between sta 208 and 255 do not indicate an approach to equilibrium beach profile shape. Instead, the beach profiles tend to be steeper than equilibrium, indicating that cross-shore profile adjustment and related shoreline recession is expected in this region. Figure 24 illustrates the typical relationship between measured and equilibrium beach profiles immediately north of the hot-spot region (October 1995). In this figure, the beach profile for sta 240 is shown to be considerably steeper than the 0.64-mm equilibrium beach profile. Neglecting additional longshore transport processes, this beach profile's shape will adjust to become closer to the shape of the equilibrium beach profile. As a consequence of this cross-shore adjustment, a corresponding recession of the shoreline position is expected. Shoreline recession because of cross-shore adjustment is not expected to exceed the anticipated adjustment from the project design.

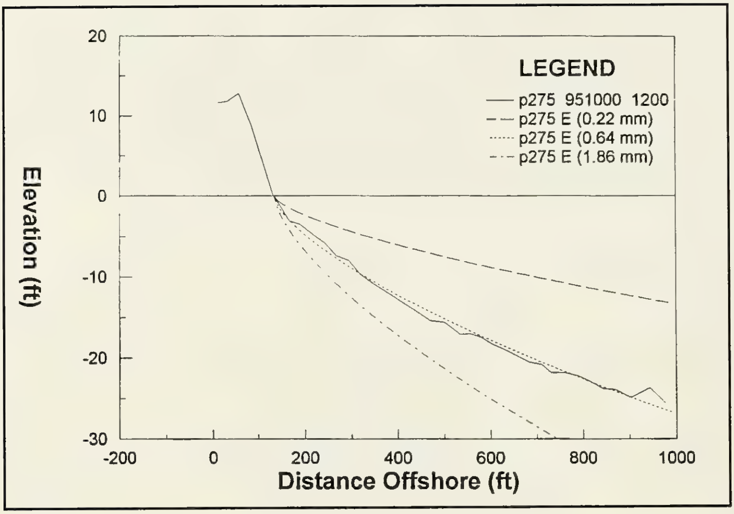

Figure 23. Beach profile and equilibrium profiles at sta 275

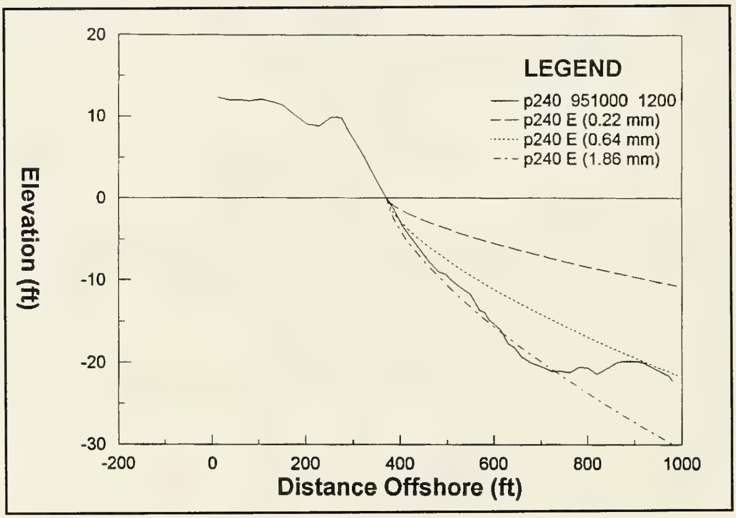

Figure 24. Beach profile and equilibrium profiles at sta 240

Summary/Conclusions

Evolution of the beach fill between sta 255 and 275 (hot-spot region) indicates that shoreline recession at the hot spot is not a product of cross-shore sediment transport. In fact, little material was moved in the offshore direction. Net losses from these beach profiles suggest that the loss of material from the hot-spot region is due to longshore transport. Beach profiles to the north of the hot-spot region indicate significant gains of material during a period in which no beach-fill material was placed, thus support the idea of longshore losses. Additional shoreline retreat because of cross-shore sediment transport is not likely in the hot-spot region because of the beach profile's near-equilibrium shape. However, additional shoreline retreat because of longshore transport cannot be dismissed.

Beach profiles to the north of the hot spot, in the area that received material from the hot-spot region, are steeper than equilibrium and can be expected to adjust in the cross-shore sense towards the equilibrium beach profile if no additional material is deposited through longshore sediment transport.

4 Beach-Fill End Losses

The placement of beach nourishment fill material within the Sea Bright to Ocean Township construction project has represented a substantial perturbation in an otherwise relatively long, straight shoreline. However, within the Monmouth Beach area, this perturbation is even more pronounced, owing to the design of a more or less uniform dry beach width along the project reach and the more seaward location of existing infrastructure within Monmouth Beach as compared with adjacent properties. The shoreline perturbation of the beach fill at the hot spot can be ideally treated as a short beach fill situated upon a longer beach fill. The shoreline perturbation resulting from the placement of beach-fill material represents a disequilibrium condition, and induced sediment transport flows can be expected. These induced sediment transport flows can occur in both cross-shore and longshore directions. Dean, Healy, and Dommerholt (1993) provided a description of three phases of observed sediment transport in the vicinity of beach nourishment projects, shown in Figure 255. The effects of cross-shore sediment flows are examined in the previous chapter, whereas this analysis focuses on longshore sediment transport flows and the associated longshore equilibration.

The intent of this analysis is to examine the Monmouth Beach hot spot (with respect to Contract 1A and shorelines to the south) to estimate the magnitude of fill material expected to be removed from the placement region because of beach-fill end losses. Two approaches are employed in the following analysis: the first involves analytical solutions of the shoreline change equations, and the second, involves application of the GENESIS shoreline change model (Hanson and Kraus 1989) in an idealized manner.

Analytical Approach

The analysis summarized in this section is documented in *Beach Nourishment and Protection* (National Research Council 1995). Pelnard-Considére (1956) combined the linearized equation of sediment transport and the equation of continuity, considering the profiles to be displaced without change of form, to yield

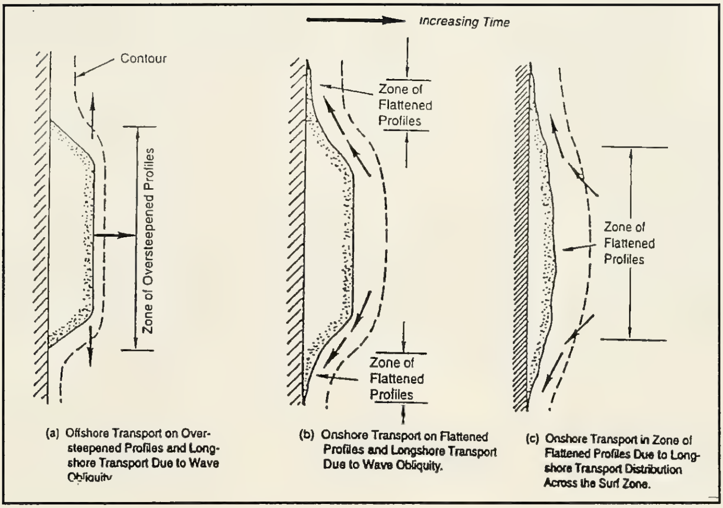

Figure 25. Three phases of observed sediment transport in vicinity of nourished projects (Note: cross-contour transport because of profile disequilibrium (from Dean et al. 1993))

$$\frac{\partial y}{\partial t} = G\frac{\partial^2 y}{\partial x^2} \tag{1}$$

in which t represents time and x and y are the longshore and cross-shore distances from the origin, respectively. The parameter G is called the alongshore diffusivity and is expressed as follows (in terms of breaking wave conditions)

$$G = \frac{K h_b^{2.5}\sqrt{g/\kappa}}{8(s-1)(1-p)(h_* + B)} \quad \text{(for breaking conditions)} \tag{2}$$

where

K = a sediment transport factor usually taken as 0.77

h_b = breaking wave height

g = acceleration of gravity

κ = ratio of breaking wave height to local water depth (usually taken as 0.78)

s = ratio of specific gravity of sediment to that of water in which it is immersed ($\approx$ 2.65)

p = porosity ($\approx$ 0.35)

h_* = depth of closure

B = berm height

It can be shown that in the absence of background erosion, the fraction of material remaining, M, in the region where fill is placed depends only on the parameter $\sqrt{Gt}/\ell$ in which ℓ is the length of the initially rectangular project and t is time (see Figure 26). For values of M between 0.5 and unity, it can be shown that an approximate expression for the relationship in Figure 26 is

$$M = 1 - \frac{2}{\sqrt{\pi}} \frac{\sqrt{Gt}}{\ell} \tag{3}$$

within a 15-percent error band in M. This equation was employed to estimate the time interval for 50 percent of the placed material to be transported from the original project limits. The standard values listed previously for K, κ, s, and p were used in all calculations. The length of the fill project, the depth of closure, and average berm height were taken as 4,100 ft (1,250 m), 29.5 ft (9.0 m), and 10.4 ft (3.17 m), respectively. In the first test, h_b was taken equal to 2.0 ft (0.6 m) (the effective wave height at the Long Branch wave gauge), resulting in G equal to 22,924 sq yd/month (19,167 sq m/month). The interval to 50 percent of placed material remaining was estimated to be 16 months. In the second test, h_b was taken equal to 3.0 ft (0.9 m) (the effective wave height at the Long Branch wave gauge shoaled to breaking conditions) to more accurately estimate breaking wave conditions. In this case, G was computed as 63,170 sq yd/month (52,818 sq m/month), and the interval to 50 percent of placed material remaining was estimated to be about 6 months.

The preceding calculations indicate that end losses from the Monmouth Beach area should be rather large, if one can consider the Monmouth Beach region as an independent beach fill because of its protrusion seaward beyond adjacent beaches. Beach profile analyses indicate that approximately 620,000 cu yd were placed between sta 264+00 and 282+00 during the period July-October 1994. Approximately 1 year later (November/December 1995), two emergency fill placements were undertaken, and approximately 230,000 cu yd were placed within this region. Assuming these emergency fills replaced fill material transported out of the placement area indicates a 37-percent loss of the initial placement volume or 63-percent retention over a 13-month interval. Both analytical predictions indicate that expected losses exceed the measured losses. The smaller magnitude of measured beach-fill losses is likely due to the fill-retaining capacity of the groins located at the ends of the Monmouth Beach hot-spot region.

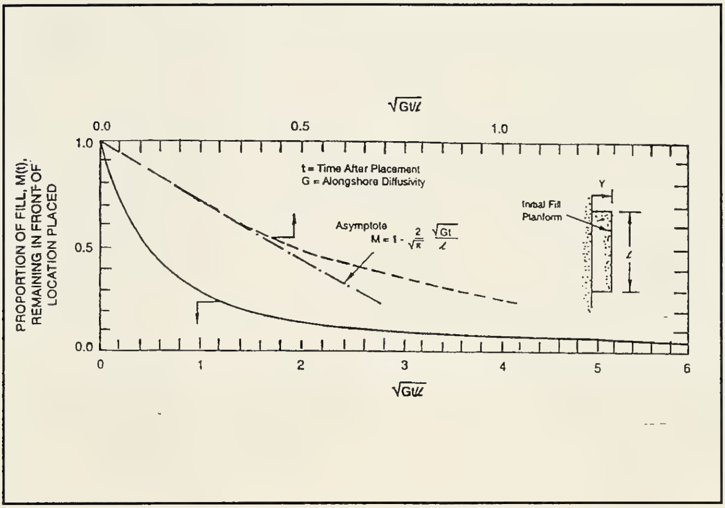

Figure 26. Proportion of material remaining, *M*, in region placed (from National Academy Press 1995)

Numerical Approach

The analysis summarized in this section involves the application of the GENESIS (Hanson and Kraus 1989) shoreline evolution model to further investigate the processes that have caused the rapid loss of beach-fill material from the Monmouth Beach hot-spot area. As idealized in the previous analytical approach, the Monmouth Beach hot spot is viewed as a short beach fill superimposed upon a larger beach fill. The GENESIS model was set up with a 20,505-ft (6,250-m) model domain containing a 4,100-ft- (1,250-m) long beach fill located in the center of the model domain. The initial berm width of the beach fill was specified as being 278 ft (85 m), estimated from the initial volume of beach-fill material placed between sta 264 and 282. The GENESIS model was calibrated to the measured volume losses using the effective wave height at the Long Branch wave gauge (H_{eff} = 2.0 ft (0.6 m), θ = 0 deg). With the idealized shoreline and effective wave conditions, the GENESIS model was calibrated (GENESIS calibration coefficients, K_1 = 0.93 and K_2 = 0.5) such that 37 percent of the fill material would be lost from the hot spot in the first 13 months after placement.

Having calibrated the GENESIS model to the available measurements, model simulations were performed using four different 1-year-long time series of wave conditions measured at the Long Branch directional wave gauge. These simulations resulted in a more realistic time sequence of shoreline evolution (e.g., more rapid losses during energetic wave events associated with winter

storms than during relatively calm summer wave conditions). The four different wave time series and repetitive model simulations were used to compute error bands at monthly intervals. The model predictions show that the observed losses from the Monmouth Beach region are reasonably well predicted using the GENESIS model. Following this analysis, another series of model simulations were performed to investigate the relative benefit of constructing a shore-perpendicular groin at the northern end of the beach fill. A groin with a length of 200 ft (61 m) was placed at the northern end of the hot-spot region (approximately the location of the existing Coastal Structure 44). Again, multiple simulations were performed using the four different wave time series to compute error bands around each of the predictions. The model results show that between 10 and 20 percent more material remains in the placement area if a groin is constructed at the northern end of the modeled reach.

This estimate is specific to the idealized conditions modeled. Additional model simulations are recommended to optimize the groin length based on the desired berm equilibrium width within the Monmouth Beach area and to determine long-term downdrift impacts of the proposed groin.

Summary and Conclusions

Figure 27 provides a summary of the calculations performed in this task. The major conclusion of this task is that the observed losses from the Monmouth Beach region can be relatively well explained by considering the region as an independent or stand-alone beach-fill project and calculating the loss of material from the region because of longshore sand transport processes. A secondary conclusion is the finding that the construction (or extension) of a shore-perpendicular groin at the northern end of the Monmouth Beach has the potential to significantly reduce the loss of fill material from the region. In addition, the construction of the Contract 2 beach fill to the south should provide an updrift supply of sand that will reduce the severity of beach erosion within the hot-spot region.

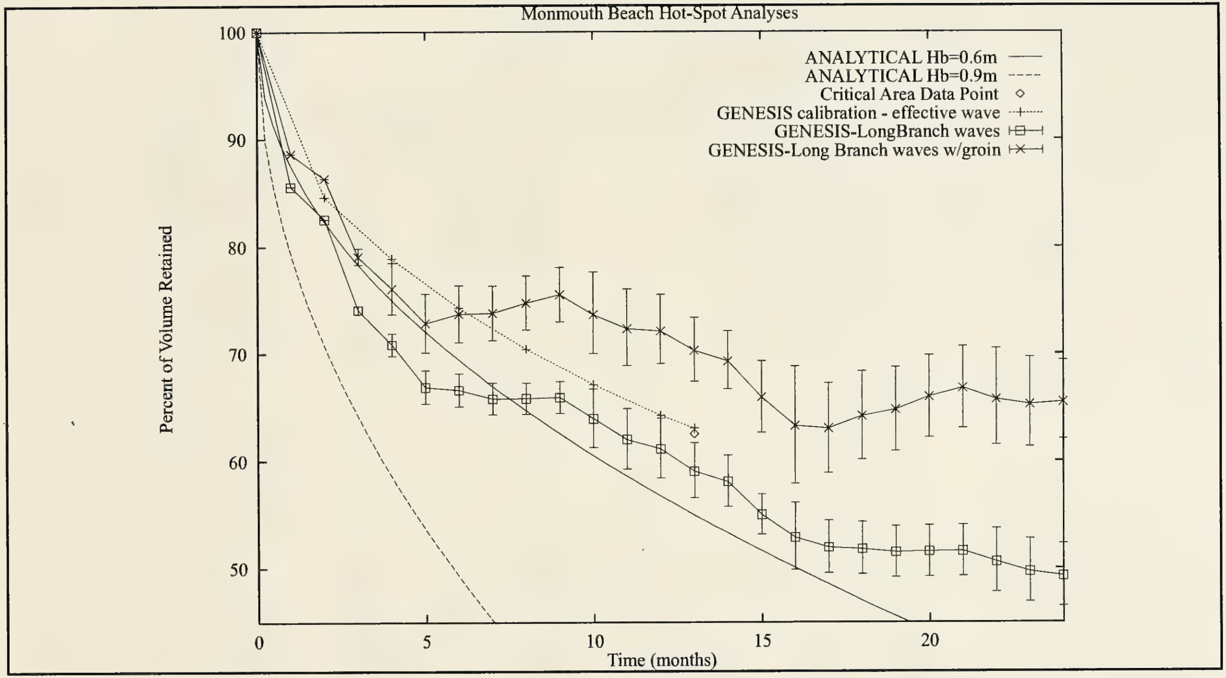

Figure 27. Estimates of percent of fill volume retained within placement area

5 Beach-Fill Planform Adjustment

The prefill shoreline at the northernmost portion of the hot-spot region protrudes significantly seaward of the adjacent shoreline because of the presence of infrastructure and the subsequent protection of this infrastructure with a seaward-protruding seawall and a curved groin (Groin 44). The planform design of the beach fill adds a 100-ft design berm to the existing shoreline, which results in the beach-fill planform protruding seaward similar to the structure-protected prefill shoreline. It is hypothesized that the severe loss of beach-fill material at the hot spot is related to this seaward protrusion of the beach-fill planform and that the beach fill will tend to adjust towards a shape and orientation similar to the offshore bathymetric contours.

As part of this analysis, three-dimensional bathymetric models were developed from beach profile surveys to evaluate the planform evolution of the shorelines and bathymetric contours. In addition, bathymetric change between sequential beach profile surveys was computed to give locations of eroded and accreted material. This analysis identifies trends in beach-fill evolution and relates these evolutionary trends to the development of the hot spot.

Data Source and Bathymetry Models

Data used in the analysis of beach planform evolution were those collected for the purpose of computing beach-fill pay quantities. These beach profile surveys were measured at various stages of completion of the beach-fill project at approximately 100-ft intervals along the beach-fill reference line over the particular reach of the project being surveyed. The beach profile surveys typically extend from the beach-fill reference line (which generally follows the seawall or revetment) to approximately 1,000 ft seaward, with maximum depths ranging from 20-25 ft. In addition to the beach profile data, a set of aerial photographs taken in April 1996 were used to digitize the mean high water (mhw) shoreline for that time and landmarks (streets, coastal structures, etc.) useful in relating the bathymetric models to the physical domain.

The profile survey data were imported into the Intergraph MGE Terrain Modeler at a 500-ft alongshore density for each respective survey time period. The beach profile data were triangulated to define a surface and then incorporated into a bathymetric grid with a horizontal resolution of 25 ft. Color-shaded contours, shorelines, and plots of bathymetric change presented in this chapter were generated using the bathymetric models developed from the beach profile survey data.

Beach-Fill Planform Evolution

The evolution of the beach-fill planform is important in understanding the transport processes that resulted in the high rates of shoreline erosion within the hot-spot region. Four plots of nearshore bathymetry are key in understanding how the beach fill evolved from prefill condition to the nourished shoreline with significant erosion at the hot-spot region. The four bathymetric models defining this evolution are given in Figures 278-31, representing the bathymetric conditions during February 1993 (prefill), October 1994, March 1995, and October 1995, respectively.

The February 1993 bathymetry (Figure 278) represents the prefill conditions along the Contract 1A reach of shoreline. Notice the sediment-starved condition of the shoreline. Only locations near groins (sta 250, 175, and 140) or where shoreline orientation decreases northbound transport potential (sta 195-205) have much dry beach. Also notice that the -20-ft contour is in general much straighter than the shoreline (which is dictated by the offsets in seawall and revetment construction as well as the presence of groins).

The October 1994 bathymetry (Figure 29) represents the constructed condition of the northern portion of the hot-spot region (to sta 255) and the adjacent, unnourished beach to the north as the beach-fill placement approached completion for the season. Note that construction did not cease until 3 January 1995,[1] but material was placed no further north than sta 245[2] at that time.

A complete profile survey of Contract 1A was performed in March 1995 to establish the condition of the beach fill before resuming construction in April. Figure 30 represents the condition of the beach fill from beach profile surveys of March 1995. During the period between October 1994 and March 1995, little beach-fill material was added to Contract 1A, and the volume that was added was placed no further north than Profile 245. Yet during this time, the region between sta 200 and 240 gained significant amounts of material, while the region

[1] Personal Communication, June 1996, Lynn Bocamazo, New York District.

[2] Personal Communication, 12 August 1996, Brian Carr, New York District

Figure 28. Nearshore bathymetry model (February 1993)

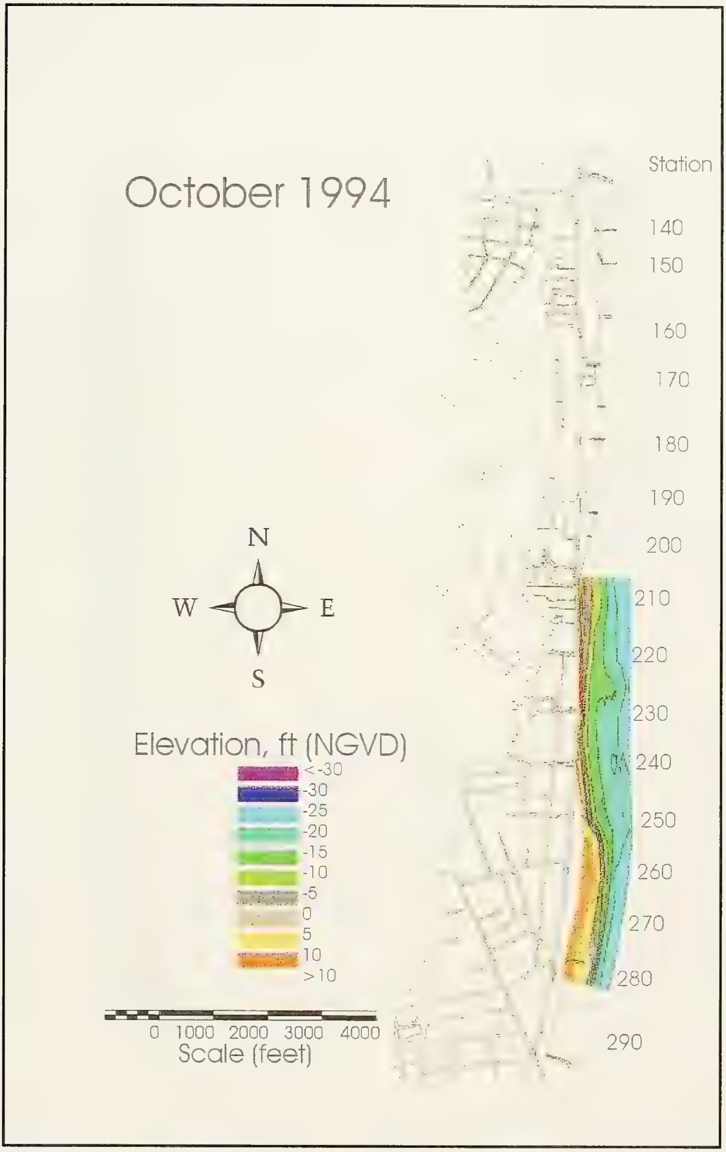

Figure 29. Nearshore bathymetry model (October 1994)

Figure 30. Nearshore bathymetry model (March 1995)

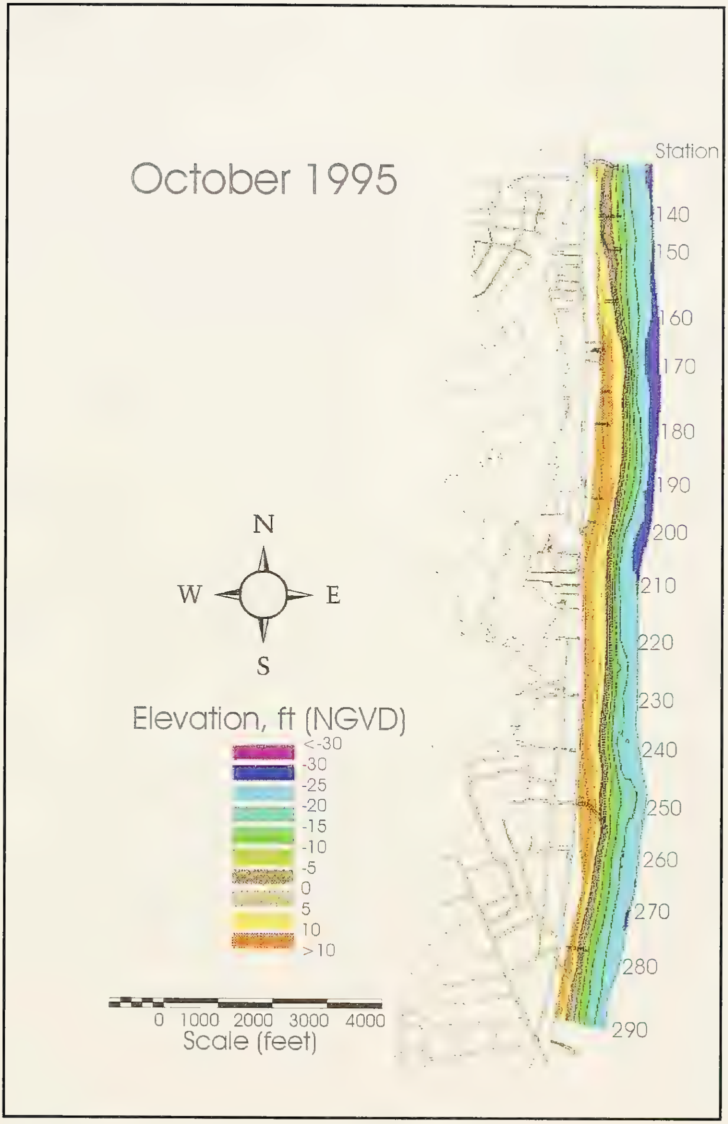

Figure 31. Nearshore bathymetry model (October 1995)

south of sta 255 lost significant volumes of material. The loss of material from the hot-spot region and the corresponding gain of material in the region to the north support the theory that beach-fill end losses play an important role in the development of the Monmouth Beach hot spot.

Proceeding in time to the October 1995 bathymetry (Figure 31), the beach fill for Contract 1A has proceeded north and is nearing completion. In the hot-spot region, additional erosion of beach-fill material has left the area with a much narrower beach and consequently less protection against storms. The erosion of the protruding beach fill has resulted in the evolution of the shoreline to a shape and orientation similar to that of the -20-ft contour of the prefill condition (Figure 278). This adjustment of the beach fill to a more "natural" configuration through the longshore transport of material apparently contributed to the development of the hot spot at Monmouth Beach. Also, from Figure 31, it appears that the most severe erosion within the hot-spot region (found at sta 275) is partially due to the downdrift effect of Coastal Structure 45 located at sta 277.

Evolution of the mhw shoreline over the construction cycle of Contract 1A illustrates the relationship between the loss of material from the hot-spot region and the gain of material downdrift. Figure 32 presents the mhw shorelines for February 1993 (prefill), October 1994, March 1995, October 1995, and April 1996 (sparse monitoring survey data are also presented for April 1996). The evolution of the mhw shoreline illustrates the smoothing effect of longshore transport on the shoreline perturbation presented in the construction of the beach-fill planform. The beach width, relative to the beach-fill reference line (or seawall), north of the hot spot has increased at the expense of the beach width within the hot-spot region.

Additional support of the beach-fill end-loss hypothesis is found in an elevation difference plot between the October 1994 and March 1995 bathymetric models (Figure 33). In this plot, the loss of material from the northern portion of the hot-spot region is evident along with material placed between October and December 1994 near sta 245. The elevation gained in the 3,200-ft alongshore region between sta 208 and 240 represents a significant volume of material—material presumably transported from the hot-spot region. Coverage of the October 1994 beach profile surveys is insufficient to determine volume lost from the hot spot versus volume gained in the adjacent region to the north.

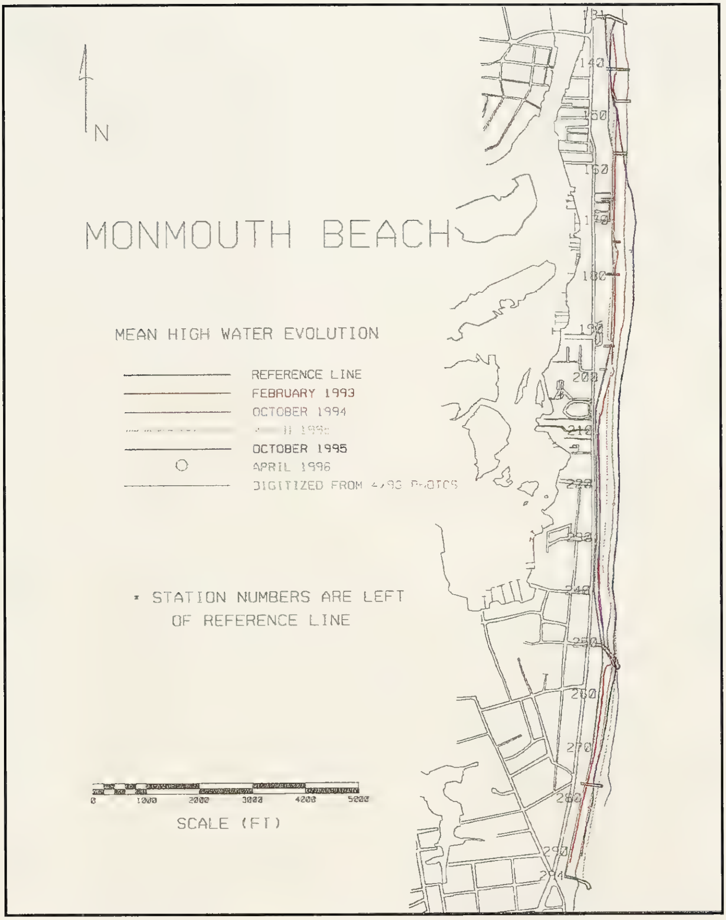

Figure 32. Evolution of mean high water shoreline

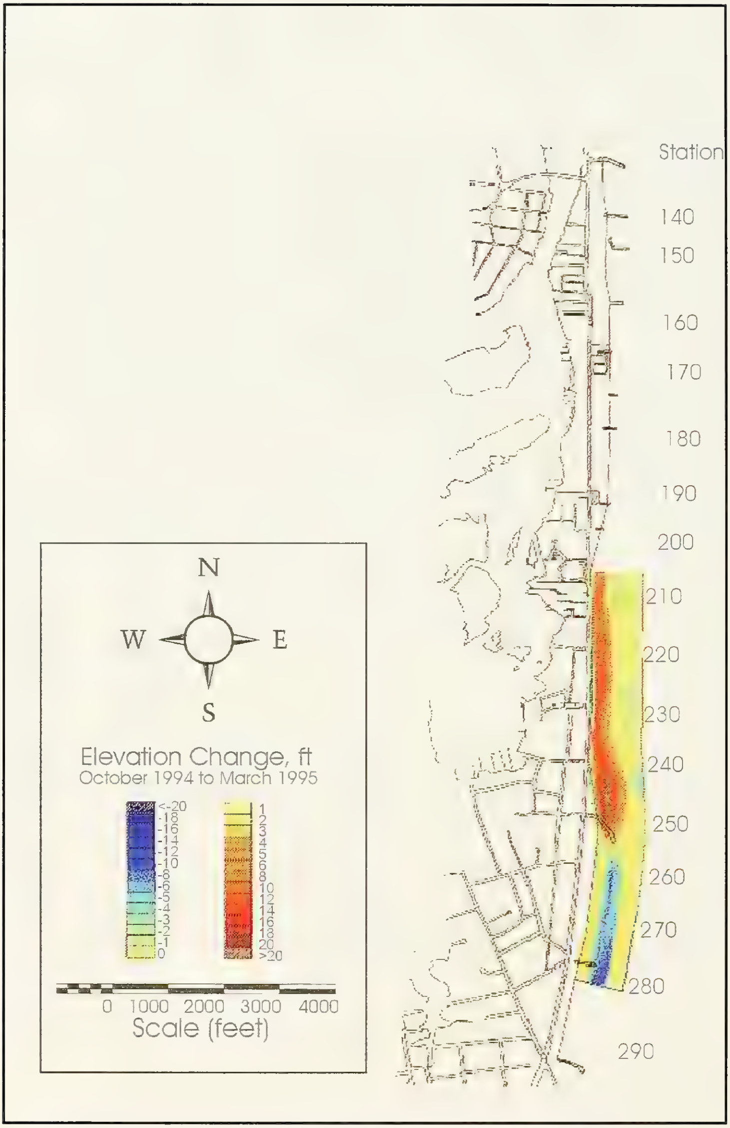

Figure 33. Elevation difference (March 1995 versus October 1994)

Conclusions

Evaluation of the planform evolution of the beach-fill project in the vicinity of the hot spot supports the findings of the beach-fill end-loss analysis. The visualization of measured beach profile data in a three-dimensional model reveals that material lost from the hot-spot region was gained in the sediment-starved profiles to the north as indicated by elevation change between the October 1994 and March 1995 bathymetric models. Analysis of the evolution of the mhw shoreline reveals that the seaward protrusion of the beach fill in the hot-spot region adjusted to the general shape and orientation of the -20-ft prefill contour. Now that longshore beach-fill adjustment has smoothed the shoreline, erosion rates within the hot-spot region are expected to decrease.

6 Conclusions

Evidence presented in the evaluation of beach-fill end losses indicates that the hot spot at Monmouth Beach is due to accelerated losses associated with the seaward protrusion of the beach fill in the region between sta 255 and 295. The remaining hypotheses either are unsupported or support the theory of beach-fill end losses as being the primary factor in the development of the hot spot. A brief summary of the results of each hypothesis is presented below relating each to the conclusions of this study.

The effect of wave focusing by Shrewsbury Rocks on the hot-spot area was evaluated by analyzing the local wave climate. Shrewsbury Rocks are located approximately 4,500 ft (0.85 mile) to the northeast of the northernmost boundary of the hot-spot region. A directional wave gauge stationed offshore of Long Branch, New Jersey, provided wave data for the time period from start of beach-fill placement (June 1994) through March 1996 (well after recognition of the hot spot). Wave statistics indicate that an insignificant number of wave events approach from north of east and those that do approach shore from that direction have low wave heights and short periods because of the sheltering by Long Island, NY. Previous work by Kraus et al. (1988) indicates that wave focusing may occur at approximately sta 218 (0.7 mile north of hot spot) and slightly northward for the wave climate evident in this study. The conclusions of this portion of the study are that Shrewsbury Rocks does not likely affect the hot spot by the focusing of wave energy, but offshore bathymetric contours angling from the hot spot towards the rocks may increase breaking wave angles and accelerate northerly longshore sediment transport.

Evaluation of cross-shore adjustment of the construction template within the hot-spot region indicates that little if any cross-shore movement of material has occurred. In fact, longshore processes dominate the evolution of the profiles within the hot-spot region. Each profile within the hot-spot region indicates net losses of material from the profile, indicative of longshore gradients in sediment transport. Further analysis of the profiles north of the hot-spot region indicates significant gains in material even during breaks in beach-fill placement. The significant net gains in beach profile volume to the north indicate that material lost from the hot-spot area was deposited in the adjacent, sediment-starved profiles to the north. In addition to the analysis of beach profile evolution, equilibrium beach profiles were superimposed upon the October 1995 beach profiles to assess the equilibrium condition of the beach profiles in the hot-spot

region. This analysis revealed that the beach profiles in the hot-spot region were near to equilibrium condition and should not adjust further by cross-shore sediment transport processes. However, the more recently constructed beach profiles to the north have profile shapes significantly steeper than the equilibrium profile and will adjust in the cross-shore sense, resulting in recession of the shoreline (neglecting any additional gains or losses because of longshore sediment transport processes).

Beach-fill end losses were established as a major contributor to the development of the Monmouth Beach hot spot through both analytical and idealized numerical evaluations. An analytical procedure to estimate the end losses from the beach fill protruding seaward of the adjacent fills and shoreline indicates that more than 50 percent of the placed volume could be expected to be lost from the region associated with beach-fill end losses. This estimate is greater than the approximately 40 percent of material actually lost, but neglects the presence of the two groins at the boundaries that serve to retard longshore sediment transport. The idealized numerical model study reasonably represents the measured losses and indicates that mitigative action in the form of groin extensions may be effective in reducing the losses from the hot-spot region. An estimated increase in beach-fill retention of 10-20 percent was estimated using the idealized model configuration, but for implementation of such a plan, detailed investigation is recommended.

Evaluation of the planform evolution of the beach-fill project in the vicinity of the hot spot supports the findings of the beach-fill end-loss analysis. The visualization of measured beach profile data in a three-dimensional model reveals that material lost from the hot-spot region was gained in the sediment-starved profiles to the north. Analysis of the evolution of specific offshore contours reveals that the seaward protrusion of the beach fill in the hot-spot region adjusted to the general shape and orientation of offshore contours.

The combined theoretical beach-fill end-loss computations and supporting bathymetric data convincingly point to beach-fill end losses as the primary factor causing the hot spot at Monmouth Beach. In addition, the offshore bathymetric contours may cause an increase in northerly sediment transport within the hot spot, further contributing to the longshore sediment losses. In efforts to maintain a protective beach in the hot-spot region to protect inland structures, this study suggests the modification of existing groins as a conceptual mitigative action to protect the 100-ft design berm. A detailed analysis of the impacts of groin modifications is recommended.

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Appendix A
Wave Statistics

Appendix A is composed of three sections. Appendix A1 presents tabular statistics of directional wave measurements made between January 1994 and March 1996 in 10 m water depth at Long Branch, New Jersey (gauge location: 40.30° N, 73.97° W). Appendix A2 presents statistical tables in the form of Appendix A1 for the National Data Buoy Center (NDBC) Buoy 44025, located south of Long Island at 40.25° N, 73.17° W in a water depth of 40 m. Statistics for NDBC Buoy 44025 were computed for the period January 1994 through February 1996. Appendix A3 presents time-series wave conditions (wave height, wave period, and direction) for 19 storms (defined by wave height greater than 2.0 m) from the Long Branch directional gauge.

A1. LONG BRANCH WAVE STATISTICS

LONG BRANCH, NJ
LONG BRANCH, NEW JERSEY 1994 - 1996
LAT: 40.30 N, LONG: 73.97 W, DEPTH:-999 M
SUMMARY OF WAVE INFORMATION BY MONTH

OCCURRENCES OF WAVE HEIGHT BY MONTH FOR ALL YEARS

Hmo(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
0.00 - 0.49	123	182	164	59	69	77	74	155	135	196	138	133	1505	30.6
0.50 - 0.99	147	96	125	109	99	92	171	137	136	132	100	31	1375	27.9
1.00 - 1.49	52	44	50	12	15	9	6	52	66	33	28	16	383	7.8
1.50 - 1.99	28	13	14	.	3	1	.	28	11	10	11	1	120	2.4
2.00 - 2.49	8	4	5	.	.	.	.	.	3	1	8	3	32	0.7
2.50 - 2.99	6	2	2	.	.	.	.	.	.	.	2	.	12	0.2
3.00 - 3.49	5	.	2	.	.	.	.	.	1	.	2	.	10	0.2
3.50 - 3.99	2	.	3	.	.	.	.	.	1	.	1	.	7	0.1
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
5.00 - 5.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
5.50 - 5.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
6.00 - 6.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
6.50 - 6.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
7.00 - 7.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
7.50 - 7.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
8.00 - 8.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
8.50 - 8.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
9.00 - 9.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
9.50 - 9.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
10.00-GREATER	.	.	.	.	.	.	.	.	.	.	.	.	0	0
BAD DATA	187	169	193	180	186	181	121	.	7	.	70	188	1482	30.1
TOTAL	558	510	558	360	372	360	372	372	360	372	360	372	4926	100.0

OCCURRENCES OF PEAK PERIOD BY MONTH FOR ALL YEARS

Tp(sec)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
3.0 - 3.9	5	9	9	10	10	9	.	9	11	35	16	8	131	2.7
4.0 - 4.9	26	23	12	17	21	25	21	18	24	22	32	10	251	5.1
5.0 - 5.9	23	18	16	28	9	10	22	16	29	17	17	14	219	4.4
6.0 - 6.9	31	24	23	20	23	20	53	85	31	24	20	13	367	7.5
7.0 - 7.9	26	35	40	28	23	43	50	68	32	30	35	6	416	8.4
8.0 - 8.9	38	70	52	49	60	55	51	95	46	72	44	20	652	13.2
9.0 - 9.9	94	94	112	27	29	13	37	40	49	105	47	28	675	13.7
10.0 - 10.9	55	27	36	.	7	.	10	3	27	18	23	11	217	4.4
11.0 - 11.9	38	10	20	.	2	1	5	14	26	14	19	8	157	3.2
12.0 - 12.9	4	4	15	.	.	3	2	9	24	19	17	9	106	2.2
13.0 - 14.9	2	2	2	.	.	.	.	10	35	7	5	7	70	1.4
15.0 - 16.9	.	.	.	.	.	.	.	5	8	.	.	.	13	0.3
17.0 - 18.9	.	.	.	.	.	.	.	.	.	.	.	.	0	0
19.0 - LONGER	.	.	.	.	.	.	.	.	.	.	.	.	0	0
BAD DATA	216	194	221	181	188	181	121	.	18	9	85	238	1652	33.5
TOTAL	558	510	558	360	372	360	372	372	360	372	360	372	4926	100.0

OCCURRENCES OF PEAK DIRECTION BY MONTH FOR ALL YEARS

Dp(deg) Direction Band & Center	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
348.75 - 11.24 (0.0)	.	.	.	.	.	.	.	.	.	.	.	.	0	0.0
11.25 - 33.74 (22.5)	.	2	1	.	.	.	.	.	.	.	1	1	5	0.1
33.75 - 56.24 (45.0)	1	4	1	.	1	.	.	.	2	4	6	1	20	0.4
56.25 - 78.74 (67.5)	2	2	2	.	.	.	.	3	4	6	5	3	27	0.6
78.75 - 101.24 (90.0)	38	24	44	4	8	2	2	57	50	53	63	47	392	8.0
101.25 - 123.74 (112.5)	93	69	95	36	53	25	38	115	174	154	77	36	965	19.6
123.75 - 146.24 (135.0)	45	50	100	101	81	116	148	152	89	107	76	34	1099	22.3
146.25 - 168.74 (157.5)	2	14	22	32	26	33	60	42	20	34	41	10	336	6.8
168.75 - 191.24 (180.0)	.	.	2	6	15	3	3	3	1	5	6	2	46	0.9
191.25 - 213.74 (202.5)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
213.75 - 236.24 (225.0)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
236.25 - 258.74 (247.5)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
258.75 - 281.24 (270.0)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
281.25 - 303.74 (292.5)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
303.75 - 326.24 (315.0)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
326.25 - 348.74 (337.5)	.	.	.	.	.	.	.	.	.	.	.	.	0	0
BAD DATA	377	345	291	181	188	181	121	.	20	9	85	238	2036	41.3
TOTAL	558	510	558	360	372	360	372	372	360	372	360	372	4926	100.0

OCCURRENCES OF WAVE HEIGHT AND PEAK PERIOD FOR 45-DEG DIRECTION BANDS

(337.50 - 22.49) 0.0 DEG
Tp(sec)

Hmo(m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	1	.	.	.	.	.	.	.	.	.	1
1.00 - 1.99	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.99	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	1	0	0	0	0	0	0	0	0	0	1

(22.50 - 67.49) 45.0 DEG
Tp(sec)

Hmo(m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	30	.	.	.	.	.	.	.	.	.	30
1.00 - 1.99	3	.	.	.	.	.	.	.	.	.	3
2.00 - 2.99	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	33	0	0	0	0	0	0	0	0	0	33

(67.50 - 112.49) 90.0 DEG

Hmo(m)	Tp(sec) 3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	80	63	119	176	140	33	1	.	.	.	612
1.00 - 1.99	17	81	74	31	10	.	.	.	.	.	213
2.00 - 2.99	.	4	13	1	1	.	.	.	.	.	19
3.00 - 3.99	.	.	3	3	3	.	.	.	.	.	9
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	97	148	209	211	154	33	1	0	0	0	853

(112.50 - 157.49) 135.0 DEG

Hmo(m)	Tp(sec) 3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	81	288	675	458	67	24	5	.	.	.	1598
1.00 - 1.99	4	46	75	46	15	13	7	.	.	.	206
2.00 - 2.99	.	.	10	1	.	.	.	.	.	.	11
3.00 - 3.99	.	.	.	2	.	.	.	.	.	.	2
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	85	334	760	507	82	37	12	0	0	0	1817

(157.50 - 202.49) 180.0 DEG

Hmo(m)	Tp(sec) 3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	136	48	2	.	.	.	.	.	.	.	186
1.00 - 1.99	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.99	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	136	48	2	0	0	0	0	0	0	0	186

(202.50 - 247.49) 225.0 DEG

Hmo(m) \ Tp(sec)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	.	.	.	.	.	.	.	.	.	.	0
1.00 - 1.99	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.99	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	0	0	0	0	0	0	0	0	0	0

(247.50 - 292.49) 270.0 DEG

Hmo(m) \ Tp(sec)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	.	.	.	.	.	.	.	.	.	.	0
1.00 - 1.99	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.99	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	0	0	0	0	0	0	0	0	0	0

(292.50 - 337.49) 315.0 DEG

Hmo(m) \ Tp(sec)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	.	.	.	.	.	.	.	.	.	.	0
1.00 - 1.99	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.99	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.99	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	0	0	0	0	0	0	0	0	0	0	0

ALL DIRECTIONS

Tp(sec)

Hmo(m)	3.0- 4.9	5.0- 6.9	7.0- 8.9	9.0- 10.9	11.0- 12.9	13.0- 14.9	15.0- 16.9	17.0- 18.9	19.0- 20.9	21.0- LONGER	BAD DATA	TOTAL
0.00 - 0.99	357	433	852	781	224	57	6	.	.	.	170	2880
1.00 - 1.99	25	149	177	99	33	13	7	.	.	.	.	503
2.00 - 2.99	.	4	34	4	2	.	.	.	.	.	.	44
3.00 - 3.99	.	.	5	8	4	.	.	.	.	.	.	17
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	0
BAD DATA	.	.	.	.	.	.	.	.	.	.	1482	1482
TOTAL	382	586	1068	892	263	70	13	0	0	0	335	4926

SUMMARY OF MEAN Hmo(m) BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1994	0.72	0.66	0.69	0.62	0.63	0.58	0.58	0.57	0.56	0.51	0.67	0.00	0.62
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.85	0.85	0.67	0.72	0.46	0.70
1996	0.92	0.61	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.82	0.63	0.70	0.62	0.63	0.58	0.59	0.71	0.72	0.59	0.70	0.46	

MAX Hmo(m)*10 WITH ASSOCIATED Tp(sec) AND Dp(deg/10) BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
1994	3810**	31 9**	4112**	13 510	17 812	18 914	11 715	19 810	36 911	21 711	24 811	0 0 0	4112**
1995	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	10 813	19 710	18 713	20 912	421110	25 810	421110
1996	391210	17 6 6	38 9 9	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	391210
MAX	391210	31 9**	4112**	13 510	17 812	18 914	11 715	19 710	36 911	21 711	421110	25 810	

** bad direction data

MAX Hmo(m): 4.2 MAX Tp(sec): 11. MAX Dp(deg): 98. DATE(gmt): 95111501

A2. LONG ISLAND WAVE STATISTICS

LONG ISLAND, NY
LONG ISLAND, NEW YORK 1994 - 1996
LAT: 40.25 N, LONG: 73.17 W, DEPTH:-999 M
SUMMARY OF WAVE INFORMATION BY MONTH

OCCURRENCES OF WAVE HEIGHT BY MONTH FOR ALL YEARS

Hmo(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
0.00 - 0.49	61	114	126	140	77	178	213	202	72	98	52	115	1448	7.6
0.50 - 0.99	402	488	472	605	684	649	851	535	464	681	221	400	6452	34.0
1.00 - 1.49	626	514	468	383	415	399	220	314	448	347	248	322	4704	24.8
1.50 - 1.99	414	409	217	194	195	98	109	158	235	114	163	188	2494	13.2
2.00 - 2.49	290	247	100	59	39	39	22	93	100	115	91	142	1337	7.1
2.50 - 2.99	182	93	18	10	11	26	1	76	41	45	62	121	686	3.6
3.00 - 3.49	86	52	5	1	11	4	.	62	14	9	46	37	327	1.7
3.50 - 3.99	48	28	8	.	.	1	.	7	5	3	31	18	149	0.8
4.00 - 4.49	21	15	4	.	.	.	.	.	4	.	1	3	48	0.3
4.50 - 4.99	17	1	4	.	.	.	.	.	2	.	.	1	25	0.1
5.00 - 5.49	8	.	2	.	.	.	.	.	1	.	.	2	13	0.1
5.50 - 5.99	4	.	4	.	.	.	.	.	.	.	.	3	11	0.1
6.00 - 6.49	5	.	3	.	.	.	.	.	.	.	.	.	8	0
6.50 - 6.99	3	.	4	.	.	.	.	.	.	.	.	.	7	0
7.00 - 7.49	1	.	3	.	.	.	.	.	.	.	.	.	4	0
7.50 - 7.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
8.00 - 8.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
8.50 - 8.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
9.00 - 9.49	.	.	.	.	.	.	.	.	.	.	.	.	0	0
9.50 - 9.99	.	.	.	.	.	.	.	.	.	.	.	.	0	0
10.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	.	0	0
BAD DATA	64	79	50	48	56	46	72	41	54	76	525	136	1247	6.6
TOTAL	2232	2040	1488	1440	1488	1440	1488	1488	1440	1488	1440	1488	18960	100.0

OCCURRENCES OF PEAK PERIOD BY MONTH FOR ALL YEARS

Tp(sec)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
3.0 - 3.9	85	99	76	117	50	65	67	38	122	160	71	137	1087	5.7
4.0 - 4.9	262	280	189	150	197	190	100	93	219	192	157	234	2263	11.9
5.0 - 5.9	470	406	173	268	198	178	225	171	207	187	248	292	3023	15.9
6.0 - 6.9	205	218	84	171	130	177	297	246	106	69	104	123	1930	10.2
7.0 - 7.9	221	248	126	254	316	353	328	340	126	158	82	98	2650	14.0
8.0 - 8.9	126	186	151	209	147	213	113	184	81	116	50	60	1636	8.6
9.0 - 9.9	208	257	233	138	190	125	95	94	93	218	53	119	1823	9.6
10.0 - 10.9	307	206	219	23	75	55	86	52	80	169	55	108	1435	7.6
11.0 - 11.9	251	37	85	18	99	21	69	84	104	68	35	78	949	5.0
12.0 - 12.9	24	22	63	21	30	17	31	71	86	36	56	45	502	2.7
13.0 - 14.9	5	2	30	20	.	.	5	60	126	39	4	49	340	1.8
15.0 - 16.9	3	.	.	3	.	.	.	14	36	.	.	3	59	0.3
17.0 - 18.9	.	.	.	.	.	.	.	.	.	.	.	.	0	0
19.0 - LONGER	1	.	.	.	.	.	.	.	.	.	.	.	1	0
BAD DATA	64	79	59	48	56	46	72	41	54	76	525	142	1262	6.7
TOTAL	2232	2040	1488	1440	1488	1440	1488	1488	1440	1488	1440	1488	18960	100.0

OCCURRENCES OF PEAK DIRECTION BY MONTH FOR ALL YEARS

Dp(deg) Direction Band & Center	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
348.75 - 11.24 (0.0)	13	26	10	8	7	3	5	21	20	31	11	18	173	0.9
11.25 - 33.74 (22.5)	14	16	12	11	1	3	.	6	17	11	9	17	117	0.6
33.75 - 56.24 (45.0)	31	20	8	4	2	3	6	8	10	12	20	19	143	0.7
56.25 - 78.74 (67.5)	101	59	27	22	59	45	13	67	21	27	23	46	510	2.7
78.75 - 101.24 (90.0)	197	198	258	51	331	66	18	168	165	173	24	133	1782	9.4
101.25 - 123.74 (112.5)	284	249	349	215	216	175	122	220	301	325	83	241	2780	14.7
123.75 - 146.24 (135.0)	350	218	186	241	171	337	222	309	286	206	122	135	2783	14.7
146.25 - 168.74 (157.5)	359	187	216	274	139	338	352	244	144	130	101	98	2582	13.6
168.75 - 191.24 (180.0)	141	200	88	255	183	232	477	241	80	103	73	32	2105	11.1
191.25 - 213.74 (202.5)	65	129	15	154	179	119	124	112	126	78	129	37	1267	6.7
213.75 - 236.24 (225.0)	39	54	7	41	61	60	45	33	48	94	46	36	564	3.0
236.25 - 258.74 (247.5)	31	61	3	3	3	.	8	1	22	9	16	23	180	0.9
258.75 - 281.24 (270.0)	200	219	78	13	26	1	6	5	62	60	87	93	850	4.5
281.25 - 303.74 (292.5)	277	277	112	84	34	6	9	4	53	96	150	347	1449	7.6
303.75 - 326.24 (315.0)	39	26	28	8	3	4	2	.	16	27	9	47	209	1.1
326.25 - 348.74 (337.5)	26	21	28	5	17	2	7	6	12	25	11	21	181	1.0
BAD DATA	65	80	63	51	56	46	72	43	57	81	526	145	1285	6.8
TOTAL	2232	2040	1488	1440	1488	1440	1488	1488	1440	1488	1440	1488	18960	100.0

OCCURRENCES OF WAVE HEIGHT AND PEAK PERIOD FOR 45-DEG DIRECTION BANDS

(337.50 - 22.49) 0.0 DEG

Tp(sec)

Hmo(m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	163	.	.	.	.	.	.	.	.	.	163
1.00 - 1.99	134	19	.	.	.	.	.	.	.	.	153
2.00 - 2.99	.	2	.	.	.	.	.	.	.	.	2
3.00 - 3.99	.	1	.	.	.	.	.	.	.	.	1
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	297	22	0	0	0	0	0	0	0	0	319

(22.50 - 67.49) 45.0 DEG

Tp(sec)

Hmo(m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	120	22	.	.	.	1	2	.	.	.	145
1.00 - 1.99	86	97	2	.	.	.	.	.	.	.	185
2.00 - 2.99	.	26	6	.	.	.	.	.	.	.	32
3.00 - 3.99	.	.	11	.	.	.	.	.	.	.	11
4.00 - 4.99	.	.	1	1	.	.	.	.	.	.	2
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	206	145	20	1	0	1	2	0	0	0	375

(67.50 - 112.49) 90.0 DEG

Hmo (m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	190	221	240	391	231	56	3	.	.	1	1333
1.00 - 1.99	77	444	273	412	198	43	.	.	.	.	1447
2.00 - 2.99	.	115	250	102	58	19	1	.	.	.	545
3.00 - 3.99	.	2	52	36	20	.	.	.	.	.	110
4.00 - 4.99	.	.	13	18	2	.	.	.	.	.	33
5.00 - 5.99	.	.	1	10	7	1	.	.	.	.	19
6.00 - 6.99	.	.	.	4	8	.	.	.	.	.	12
7.00 - 7.99	.	.	.	.	4	.	.	.	.	.	4
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	267	782	829	973	528	119	4	0	0	1	3503

(112.50 - 157.49) 135.0 DEG

Hmo (m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	102	342	1288	1008	284	56	13	.	.	.	3093
1.00 - 1.99	43	211	458	587	254	59	6	.	.	.	1618
2.00 - 2.99	.	28	87	144	194	53	19	.	.	.	525
3.00 - 3.99	.	1	18	59	112	19	3	.	.	.	212
4.00 - 4.99	.	.	2	13	12	5	.	.	.	.	32
5.00 - 5.99	.	.	.	1	2	2	.	.	.	.	5
6.00 - 6.99	.	.	.	.	3	.	.	.	.	.	3
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	145	582	1853	1812	861	194	41	0	0	0	5488

(157.50 - 202.49) 180.0 DEG

Hmo (m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	TOTAL
0.00 - 0.99	386	760	471	162	17	.	1	.	.	.	1797
1.00 - 1.99	103	653	844	178	18	12	.	.	.	.	1808
2.00 - 2.99	1	57	181	100	7	13	11	.	.	.	370
3.00 - 3.99	.	.	14	29	19	.	.	.	.	.	62
4.00 - 4.99	.	.	1	3	1	.	.	.	.	.	5
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	490	1470	1511	472	62	25	12	0	0	0	4042

(202.50 - 247.49) 225.0 DEG

Tp(sec)

Hmo(m)	3.0- 4.9	5.0- 6.9	7.0- 8.9	9.0- 10.9	11.0- 12.9	13.0- 14.9	15.0- 16.9	17.0- 18.9	19.0- 20.9	21.0- LONGER	TOTAL
0.00 - 0.99	523	49	1	.	.	1	.	.	.	.	574
1.00 - 1.99	188	398	5	.	.	.	.	.	.	.	591
2.00 - 2.99	.	57	14	.	.	.	.	.	.	.	71
3.00 - 3.99	.	.	3	.	.	.	.	.	.	.	3
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	711	504	23	0	0	1	0	0	0	0	1239

(247.50 - 292.49) 270.0 DEG

Tp(sec)

Hmo(m)	3.0- 4.9	5.0- 6.9	7.0- 8.9	9.0- 10.9	11.0- 12.9	13.0- 14.9	15.0- 16.9	17.0- 18.9	19.0- 20.9	21.0- LONGER	TOTAL
0.00 - 0.99	507	5	.	.	.	.	.	.	.	.	512
1.00 - 1.99	278	797	.	.	.	.	.	.	.	.	1075
2.00 - 2.99	.	417	10	.	.	.	.	.	.	.	427
3.00 - 3.99	.	32	38	.	.	.	.	.	.	.	70
4.00 - 4.99	.	.	1	.	.	.	.	.	.	.	1
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	785	1251	49	0	0	0	0	0	0	0	2085

(292.50 - 337.49) 315.0 DEG

Tp(sec)

Hmo(m)	3.0- 4.9	5.0- 6.9	7.0- 8.9	9.0- 10.9	11.0- 12.9	13.0- 14.9	15.0- 16.9	17.0- 18.9	19.0- 20.9	21.0- LONGER	TOTAL
0.00 - 0.99	242	3	.	.	.	.	.	.	.	.	245
1.00 - 1.99	184	137	.	.	.	.	.	.	.	.	321
2.00 - 2.99	.	51	.	.	.	.	.	.	.	.	51
3.00 - 3.99	.	6	1	.	.	.	.	.	.	.	7
4.00 - 4.99	.	.	.	.	.	.	.	.	.	.	0
5.00 - 5.99	.	.	.	.	.	.	.	.	.	.	0
6.00 - 6.99	.	.	.	.	.	.	.	.	.	.	0
7.00 - 7.99	.	.	.	.	.	.	.	.	.	.	0
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	0
TOTAL	426	197	1	0	0	0	0	0	0	0	624

ALL DIRECTIONS

Tp(sec)

Hmo(m)	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-LONGER	BAD DATA	TOTAL
0.00 - 0.99	2256	1402	2000	1561	532	114	19	.	.	1	15	7900
1.00 - 1.99	1093	2756	1582	1177	470	114	6	.	.	.	.	7198
2.00 - 2.99	1	753	548	346	259	85	31	.	.	.	.	2023
3.00 - 3.99	.	42	137	124	151	19	3	.	.	.	.	476
4.00 - 4.99	.	.	18	35	15	5	.	.	.	.	.	73
5.00 - 5.99	.	.	1	11	9	3	.	.	.	.	.	24
6.00 - 6.99	.	.	.	4	11	.	.	.	.	.	.	15
7.00 - 7.99	.	.	.	.	4	.	.	.	.	.	.	4
8.00 - 8.99	.	.	.	.	.	.	.	.	.	.	.	0
9.00 - GREATER	.	.	.	.	.	.	.	.	.	.	.	0
BAD DATA	.	.	.	.	.	.	.	.	.	.	1247	1247
TOTAL	3350	4953	4286	3258	1451	340	59	0	0	1	1262	18960

OCCURRENCES OF WIND SPEED BY MONTH FOR ALL YEARS

WS(m/sec)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
0.00 - 2.49	101	158	139	137	231	136	193	260	131	147	42	63	1738	9.2
2.50 - 4.99	297	359	448	485	487	476	673	494	294	395	121	182	4711	24.8
5.00 - 7.49	533	438	399	431	411	503	392	358	534	445	200	311	4955	26.1
7.50 - 9.99	527	441	270	237	209	232	137	246	312	256	248	355	3470	18.3
10.00 - 12.49	467	313	113	90	83	39	21	77	102	134	221	268	1928	10.2
12.50 - 14.99	169	214	54	10	11	7	.	8	7	33	66	132	711	3.8
15.00 - 17.49	49	36	5	2	.	1	.	3	6	2	17	38	159	0.8
17.50 - 19.99	19	2	9	.	.	.	.	1	.	.	.	3	34	0.2
20.00 - GREATER	6	.	1	.	.	.	.	.	.	.	.	.	7	0.0
BAD DATA	64	79	50	48	56	46	72	41	54	76	525	136	1247	6.6
TOTAL	2232	2040	1488	1440	1488	1440	1488	1488	1440	1488	1440	1488	18960	100.0

OCCURRENCES OF WIND DIRECTION BY MONTH FOR ALL YEARS

WD(deg) Direction Band & Center	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	%
337.50 - 22.49 (0.0)	219	207	136	92	100	81	46	119	167	138	54	166	1525	8.0
22.50 - 67.49 (45.0)	275	194	148	91	149	130	46	200	200	103	59	151	1746	9.2
67.50 - 112.49 (90.0)	170	111	149	149	139	194	105	103	158	89	52	76	1495	7.9
112.50 - 157.49 (135.0)	137	87	131	92	82	103	131	67	103	108	67	50	1158	6.1
157.50 - 202.49 (180.0)	205	199	204	399	354	463	481	354	232	248	153	47	3339	17.6
202.50 - 247.49 (225.0)	219	267	182	254	250	288	432	414	223	267	166	158	3120	16.5
247.50 - 292.49 (270.0)	517	604	268	194	196	72	114	102	193	234	212	279	2985	15.7
292.50 - 337.49 (315.0)	426	292	220	121	162	63	61	88	110	225	152	425	2345	12.4
BAD DATA	64	79	50	48	56	46	72	41	54	76	525	136	1247	6.6
TOTAL	2232	2040	1488	1440	1488	1440	1488	1488	1440	1488	1440	1488	18960	100.0

SUMMARY OF MEAN Hmo(m) BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1994	1.74	1.45	1.38	1.11	1.11	0.94	0.87	0.91	1.10	0.91	1.65	1.53	1.22
1995	1.67	1.56	1.13	1.00	1.05	1.01	0.83	1.54	1.46	1.33	1.27	1.34	1.26
1996	1.75	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59
MEAN	1.72	1.47	1.26	1.06	1.08	0.98	0.85	1.22	1.28	1.11	1.54	1.44	

MAX Hmo(m)*10 WITH ASSOCIATED Tp(sec) AND Dp(deg/10) BY MONTH AND YEAR

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
1994	5910 8	44 8 9	741110	24 818	341111	35 819	26 818	33 8 6	51 811	29 8 7	411012	5913 9	741110
1995	40 917	46 914	29 915	30 819	25 7 7	30 7 7	19 720	391413	331715	391111	31 820	36 8 9	46 914
1996	7211 8	37 631	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	7211 8
MAX	7211 8	46 914	741110	30 819	341111	35 819	26 818	391413	51 811	391111	411012	5913 9	

MAX Hmo(m): 7.4   MAX Tp(sec): 11.   MAX Dp(deg): 97.   DATE(gmt): 94030311

MAX WIND SPEED(m/sec): 22.   MAX WIND DIRECTION(deg): 42.   DATE(gmt): 96010805

A3. STORM DATA

date	Hmo (m)	Tp (sec)	dir (deg)
95111415	2.20	7.1	104
95111416	2.62	7.1	99
95111417	2.81	7.5	96
95111418	3.54	9.1	102
95111419	3.54	8.5	97
95111420	2.99	9.1	98
95111421	3.71	9.1	97
95111422	3.47	9.1	89
95111423	3.82	9.8	105
95111500	3.86	10.7	98
95111501	4.22	10.7	101*
95111502	3.67	11.6	107
95111503	3.22	11.6	101
95111504	3.44	10.7	104
95111505	2.69	9.8	104
95111506	2.59	9.1	104
95111507	2.78	10.7	102
95111508	2.15	8.5	109
95111509	2.14	10.7	108
95111120	2.00	7.1	137
95111121	2.24	7.1	133
95111122	2.02	7.5	139
95111200	2.00	7.1	140
95111201	2.62	7.5	132
95111202	3.22	8.0	133
95111203	3.30	8.0	136
95111204	3.35	9.8	128
95111205	4.08	9.8	129*
95111206	2.89	10.7	126
94030218	2.08	6.7	-999
94030219	2.09	6.7	-999
94030220	2.32	7.1	-999
94030221	2.22	7.1	-999
94030222	2.35	7.5	-999
94030223	2.64	8.0	-999
94030300	3.03	7.5	-999
94030301	3.20	8.5	-999
94030302	3.64	8.5	-999
94030303	3.43	8.5	-999
94030304	3.75	9.1	-999
94030305	4.01	9.8	-999
94030306	3.80	9.8	-999
94030307	3.77	10.7	-999
94030308	3.54	9.8	-999
94030309	4.07	11.6	-999*
94030310	3.94	10.7	-999
94030311	3.94	11.6	-999
94030312	3.79	11.6	-999
94030313	4.00	12.8	-999
94030314	3.57	12.8	-999
94030315	3.53	12.8	-999
94030316	3.48	10.7	-999
94030317	3.23	12.8	-999
94030319	2.56	11.6	-999
94030320	2.36	12.8	-999
94030321	2.14	11.6	-999
94030402	2.01	11.6	-999

96010719	2.28	6.4	95
96010720	2.35	6.7	86
96010721	2.41	7.5	99
96010722	2.86	8.0	92
96010723	3.05	8.0	93
96010800	3.30	8.5	98
96010801	3.39	8.5	99
96010802	3.25	9.1	102
96010803	3.80	9.1	96
96010804	3.39	9.8	102
96010805	3.64	9.8	97
96010806	3.73	10.7	103
96010807	3.69	10.7	105
96010808	3.63	11.6	103
96010809	3.61	10.7	103
96010810	3.89	10.7	104
96010811	3.90	11.6	108*
96010812	3.55	11.6	96
96010813	3.40	12.8	111
96010814	3.31	11.6	106
96010815	3.11	11.6	105
96010816	3.04	11.6	105
96010817	2.89	12.8	103
96010818	2.80	12.8	107
96010819	2.61	11.6	106
96010820	2.51	11.6	108
96010821	2.39	11.6	111
96010822	2.01	8.5	93
94010323	2.24	7.1	-999
94010400	2.17	7.5	-999
94010401	2.33	7.5	-999
94010402	2.51	7.1	-999
94010403	2.56	7.5	-999
94010404	2.53	8.0	-999
94010405	2.44	8.0	-999
94010406	2.71	9.1	-999
94010407	2.66	9.1	-999
94010408	2.50	9.1	-999
94010409	2.39	9.1	-999
94010410	2.39	9.1	-999
94010411	2.54	9.1	-999
94010412	2.65	9.8	-999
94010413	2.78	9.1	-999
94010414	3.33	9.8	-999
94010415	3.79	9.8	-999*
94010416	3.34	8.5	-999
94010417	2.54	9.8	-999
94010418	2.23	10.7	-999
94010419	2.25	9.1	-999
96031920	2.15	6.1	90
96031921	2.31	7.1	97
96031922	2.80	7.1	85
96031923	2.95	7.5	92
96032000	2.67	7.5	86
96032001	3.13	8.0	99
96032002	3.31	8.0	92
96032003	3.76	8.5	97*
96032004	2.81	8.5	93
96032005	2.31	9.1	95
96032006	2.05	8.5	100

94092219	2.09	6.7	109
94092220	2.17	6.7	99
94092221	2.35	7.1	110
94092222	2.52	7.5	107
94092223	3.02	7.5	106
94092300	3.19	8.0	109
94092301	3.24	7.5	103
94092302	3.42	8.5	113
94092303	3.36	8.5	108
94092304	3.55	8.5	107*
94092305	3.45	8.5	106
94092306	3.07	8.5	108
94092307	2.37	8.5	105
94092308	2.30	8.0	109
94092310	2.01	8.5	122
94092311	2.02	9.8	127
94092312	2.09	10.7	131
94022316	2.11	7.1	-999
94022317	2.58	7.1	-999
94022318	2.75	8.0	-999
94022319	2.88	8.0	-999
94022320	2.70	8.0	-999
94022321	2.82	8.0	-999
94022322	3.14	8.5	-999*
94022323	2.94	8.5	-999
94022400	2.85	8.5	-999
94022401	2.65	8.5	-999
94022402	2.66	9.1	-999
94022403	2.38	9.1	-999
94022404	2.07	8.5	-999
94022405	2.25	9.1	-999
94022406	2.01	8.0	-999
94022407	2.64	9.1	-999
94022408	2.28	8.5	-999
94022409	2.22	9.1	-999
94022410	2.49	9.1	-999
96011914	2.05	7.5	139
96011915	2.35	8.0	134
96011916	2.66	8.0	135
96011917	2.89	9.1	134
96011918	2.87	9.1	131
96011919	2.76	9.8	128
96011920	3.14	9.1	130*
96011921	2.71	9.1	126
96011922	2.64	9.8	128
96011923	2.08	9.8	126
96012712	2.07	7.1	129
96012718	2.27	7.1	125
96012719	2.45	7.5	131
96012720	2.98	8.0	139
96012721	3.05	9.1	133*
96012722	2.43	9.8	125
96012723	2.33	9.8	129

95121923	2.05	7.1	97
95122000	2.18	7.1	97
95122001	2.18	7.5	100
95122002	2.46	7.5	86*
95122003	2.18	8.0	97
95122004	2.35	8.0	95
95122005	2.44	8.0	100
95122006	2.29	8.0	95
95122007	2.39	8.0	95
95122008	2.26	8.5	93
95122009	2.15	8.5	102
96011220	2.24	6.1	92
96011221	2.38	6.7	96*
96011222	2.28	7.1	101
96011223	2.29	8.0	120
96011300	2.05	8.0	114
94111710	2.03	7.1	114
94111717	2.02	6.7	112
94111718	2.01	6.7	118
94111720	2.03	7.5	111
94111721	2.33	7.1	106
94111722	2.26	7.5	112
94111723	2.36	8.0	121*
94111800	2.22	8.0	117
94111801	2.29	9.1	121
94111802	2.11	9.8	114
94111803	2.14	8.0	118
94111804	2.06	7.5	117
94111805	2.10	10.7	122
94111806	2.17	7.1	116
94111807	2.12	8.0	122
94111808	2.11	7.5	117
94111809	2.28	8.5	124
94111810	2.11	8.5	125
94111811	2.09	7.1	116
94111812	2.26	8.5	120
94111813	2.14	6.4	118
96032911	2.10	6.7	88
96032912	2.33	7.1	96*
96032913	2.18	7.5	95
96032914	2.05	7.5	100
96032916	2.11	8.5	109
96032919	2.07	9.1	112
94021118	2.04	8.0	-999
94021123	2.23	8.5	-999*
94021200	2.22	8.5	-999
94021201	2.17	9.1	-999
94021203	2.07	8.5	-999
96010308	2.17	7.1	102*
96010313	2.06	8.0	113
94012612	2.11	7.1	-999*
94012613	2.10	8.0	-999
94012620	2.05	8.5	-999
94012821	2.01	8.0	-999
94012822	2.05	9.1	-999
94012823	2.11	9.1	-999*

94101512	2.06	7.5	105*
94101513	2.00	7.5	108
94101514	2.06	7.1	100
94101515	2.01	7.5	105

* Storm Peak, as determined from maximum wave height

Appendix B
Beach Profile Evolution

Appendix B contains plots of beach profile surveys along the beach fill of Contract 1A (Monmouth Beach and Seabright, New Jersey) and a grain-size distribution analysis of sediment samples collected from the beach fill at Monmouth Beach. Figures B1 through B10 present available beach profile surveys for sta 208, 224, 232, 240, 245, 255, 265, 275, 286, and 294. Figure B11 is the sieve analysis of the beach-fill material. Figures B12 through B20 compare equilibrium beach profiles with the October 1995 beach profile surveys at sta 208, 232, 240, 245, 255, 265, 275, 286, and 294.

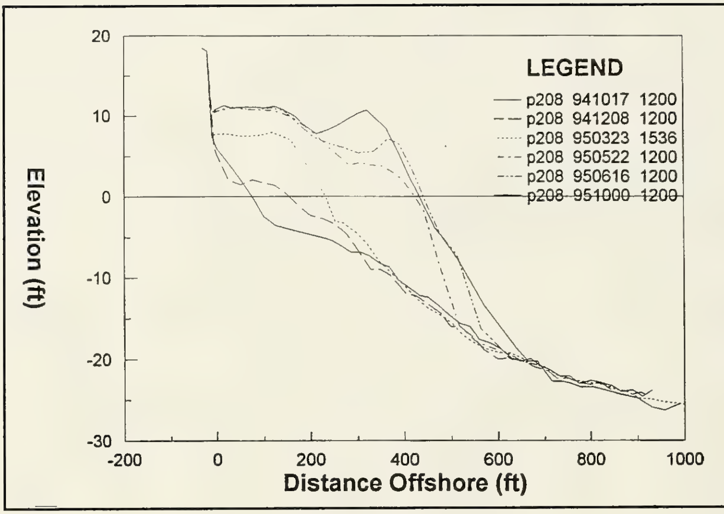

Figure B1. Beach profile evolution (sta 208)

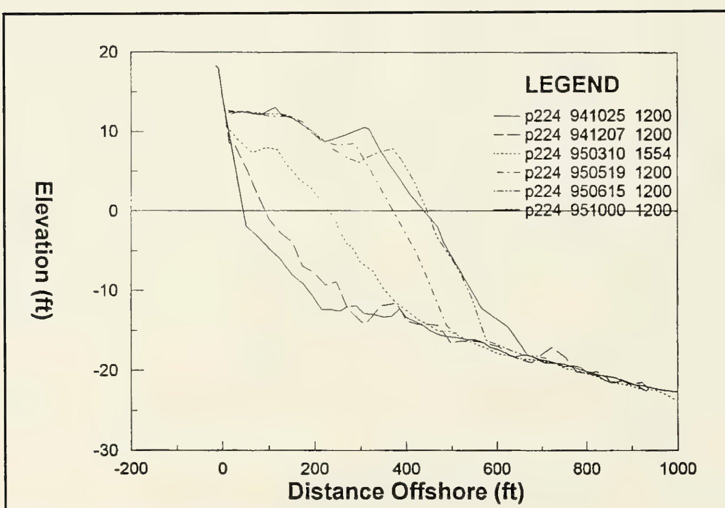

Figure B2. Beach profile evolution (sta 224)

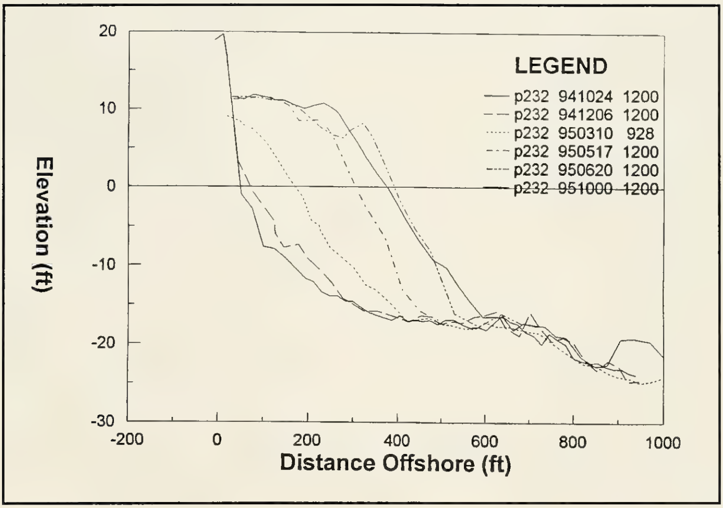

Figure B3. Beach profile evolution (sta 232)

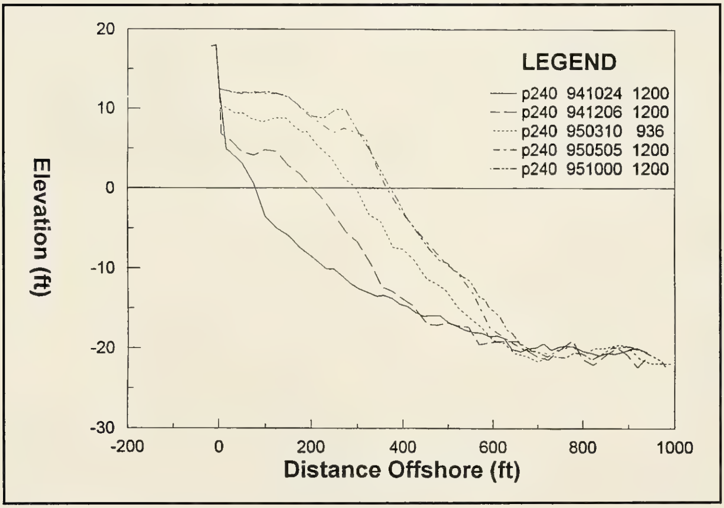

Figure B4. Beach profile evolution (sta 240)

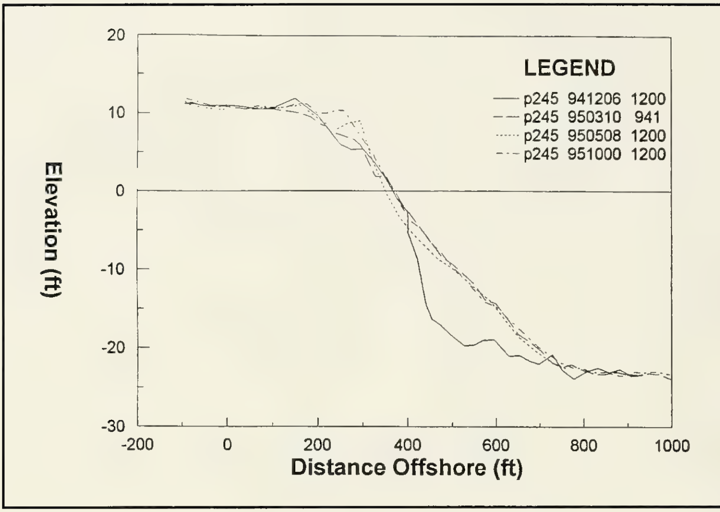

Figure B5. Beach profile evolution (sta 245)

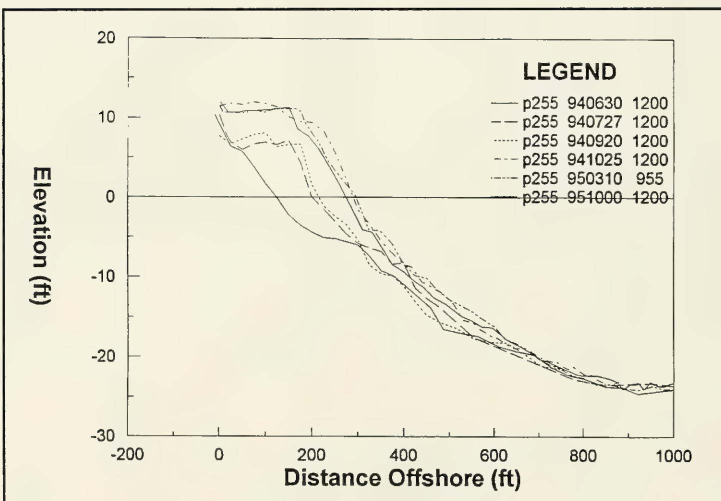

Figure B6. Beach profile evolution (sta 255)

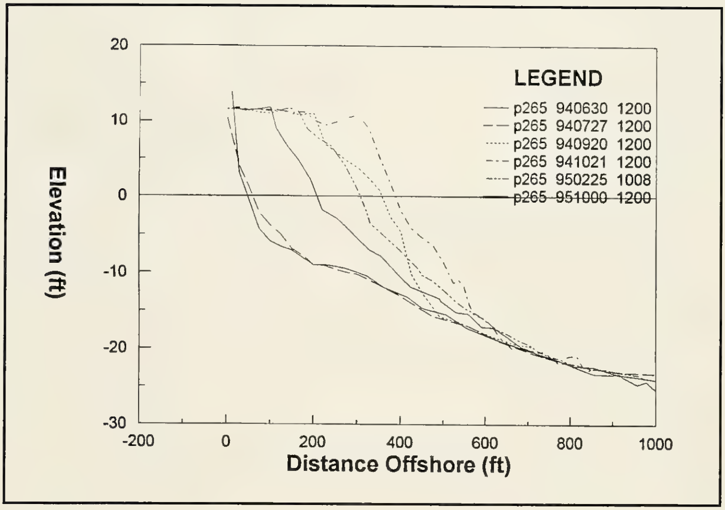

Figure B7. Beach profile evolution (sta 265)

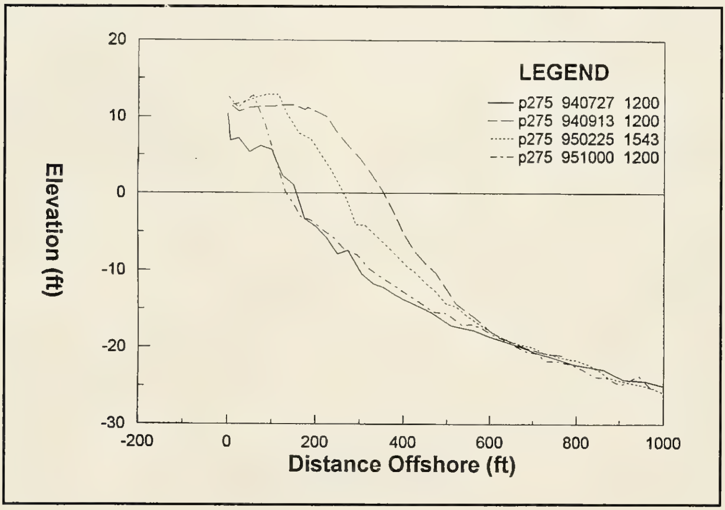

Figure B8. Beach profile evolution (sta 275)

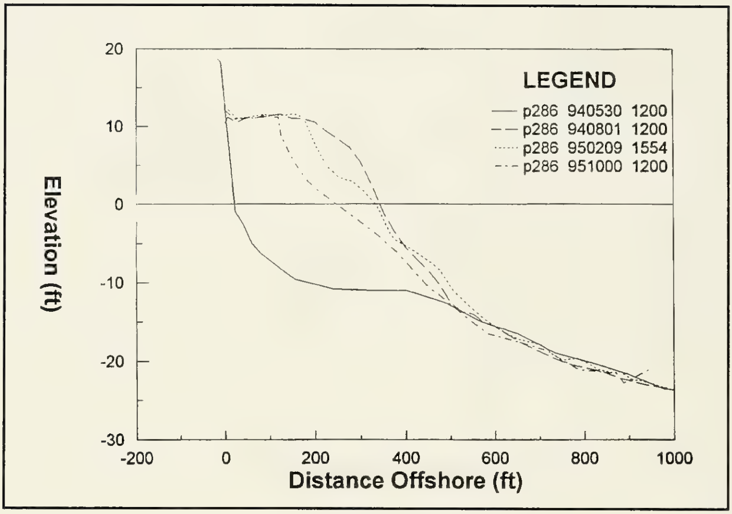

Figure B9. Beach profile evolution (sta 286)

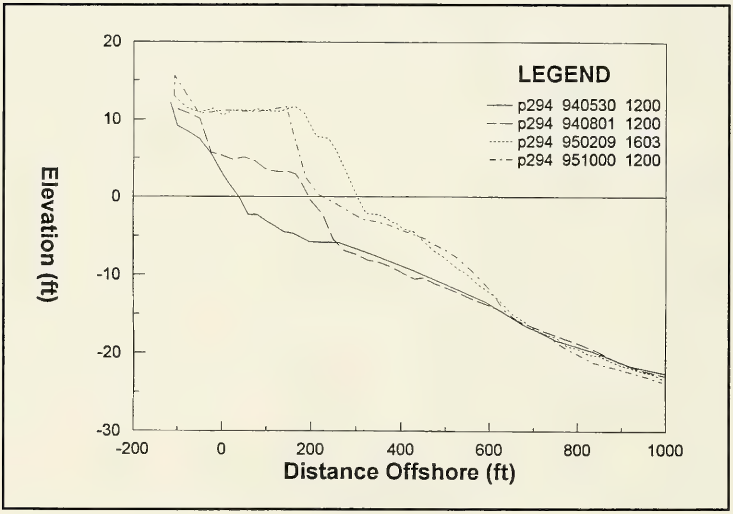

Figure B10. Beach profile evolution (sta 294)

	Backshore Beach									Edge of Berm								
	d16	d16	d50	d50	d84	d84	mean	st. dev.	kurtosis	d16	d16	d50	d50	d84	d84	mean	st. dev	kurtosis
Profile	phi	mm	phi	mm	phi	mm				phi	mm	phi	mm	phi	mm			
246	-0.4	1.32	1.1	0.47	2	0.25	0.900	1.200	-0.167	-1.7	3.25	0.7	0.62	1.8	0.29	0.267	1.750	-0.248
248	-1.7	3.25	0.3	0.81	1.6	0.33	0.067	1.650	-0.141	0	1.00	0.8	0.57	1.6	0.33	0.800	0.800	0.000
250	-0.5	1.41	0.8	0.57	1.8	0.29	0.700	1.150	-0.087	0	1.00	0.7	0.62	1.5	0.35	0.733	0.750	0.044
252	-0.8	1.74	0.9	0.54	1.8	0.29	0.633	1.300	-0.205	-0.5	1.41	1.3	0.41	2.2	0.22	1.000	1.350	-0.222
254	-1	2.00	1.2	0.44	2.2	0.22	0.800	1.600	-0.250	0.1	0.93	1.4	0.38	2	0.25	1.167	0.950	-0.248
256	-0.7	1.62	0.8	0.57	1.7	0.31	0.600	1.200	-0.167	0.2	0.87	1.3	0.41	1.8	0.29	1.100	0.800	-0.250
258	0.1	0.93	1.3	0.41	1.8	0.29	1.067	0.850	-0.275	-0.5	1.41	0.9	0.54	1.7	0.31	0.700	1.100	-0.182
260	-0.5	1.41	1	0.50	1.9	0.27	0.800	1.200	-0.167	-1	2.00	0.5	0.71	2.1	0.23	0.533	1.550	0.022
262	-0.3	1.23	1.2	0.44	2.1	0.23	1.000	1.200	-0.167	-1.1	2.14	0.7	0.62	1.8	0.29	0.467	1.450	-0.161
264	-0.5	1.41	0.8	0.57	2	0.25	0.767	1.250	-0.027	-1.3	2.46	0.4	0.76	1.8	0.29	0.300	1.550	-0.065
266	-2.3	4.92	0.2	0.87	2	0.25	-0.033	2.150	-0.109	-0.7	1.62	1	0.50	1.8	0.29	0.700	1.250	-0.240
268	0	1.00	1.1	0.47	1.7	0.31	0.933	0.850	-0.196	-2.4	5.28	-0.5	1.41	1.3	0.41	-0.533	1.850	-0.018
270	-0.5	1.41	1	0.50	1.8	0.29	0.767	1.150	-0.203	-2.3	4.92	-0.3	1.23	1.4	0.38	-0.400	1.850	-0.054
272	-0.8	1.74	1.1	0.47	2.1	0.23	0.800	1.450	-0.207	0.3	0.81	1.4	0.38	2.2	0.22	1.300	0.950	-0.105
274	-1.3	2.46	0.7	0.62	1.8	0.29	0.400	1.550	-0.194	0	1.00	0.9	0.54	1.7	0.31	0.867	0.850	-0.039
276	0.4	0.76	1.1	0.47	1.8	0.29	1.100	0.700	0.000	-0.3	1.23	1.5	0.35	2.3	0.20	1.167	1.300	-0.256
average			0.9125	0.53			0.70625	1.278125	**********			0.79375	0.58			0.635417	1.25625	**********
st. dev			0.30957									0.57442						
low			0.60293	0.66								0.21933	0.86					
high			1.22207	0.43								1.36817	0.39					

MHW									MLW								
d16	d16	d50	d50	d84	d84	mean	st dev	kurtosis	d16	d16	d50	d50	d84	d84	mean	st dev	kurtosis
phi	mm	phi	mm	phi	mm				phi	mm	phi	mm	phi	mm			
0.5	0.71	1	0.50	1.5	0.35	1.000	0.500	0.000	0.2	0.87	1	0.50	1.7	0.31	0.967	0.750	-0.044
0.5	0.71	1.1	0.47	1.6	0.33	1.067	0.550	-0.061	-1.2	2.30	-0.2	1.15	1.3	0.41	-0.033	1.250	0.133
0	1.00	0.8	0.57	1.5	0.35	0.767	0.750	-0.044	-1.2	2.30	-0.4	1.32	1.3	0.41	-0.100	1.250	0.240
-0.7	1.62	0.6	0.66	1.5	0.35	0.467	1.100	-0.121	-3.4	10.56	-2.5	5.66	1	0.50	-1.633	2.200	0.394
-0.5	1.41	0.6	0.66	1.6	0.33	0.567	1.050	-0.032	-2.8	6.96	-0.2	1.15	1.3	0.41	-0.567	2.050	-0.179
-1.5	2.83	0.5	0.71	1.7	0.31	0.233	1.600	-0.167	-0.5	1.41	0.4	0.76	1.1	0.47	0.333	0.800	-0.083
-2.2	4.59	-0.9	1.87	1.7	0.31	-0.467	1.950	0.222	-3.4	10.56	-2.1	4.29	0	1.00	-1.833	1.700	0.157
0.1	0.93	1.2	0.44	2	0.25	1.100	0.950	-0.105	-0.6	1.52	0.2	0.87	1.1	0.47	0.233	0.850	0.039
-0.3	1.23	0.7	0.62	1.8	0.29	0.733	1.050	0.032	-0.7	1.62	0.2	0.87	1.6	0.33	0.367	1.150	0.145
0.4	0.76	1.8	0.29	2.1	0.23	1.433	0.850	-0.431	-0.2	1.15	0.4	0.76	1.5	0.35	0.567	0.850	0.196
0.7	0.62	1.3	0.41	1.8	0.29	1.267	0.550	-0.061	-0.1	1.07	0.6	0.66	1.7	0.31	0.733	0.900	0.148
0	1.00	1.3	0.41	2.2	0.22	1.167	1.100	-0.121	-0.4	1.32	0.6	0.66	1.5	0.35	0.567	0.950	-0.035
-0.7	1.62	0.8	0.57	1.8	0.29	0.633	1.250	-0.133	-2.8	6.96	-1.3	2.46	0.8	0.57	-1.100	1.800	0.111
1	0.50	1.5	0.35	2	0.25	1.500	0.500	0.000	-2	4.00	0.6	0.66	1.7	0.31	0.100	1.850	-0.270
-0.3	1.23	1	0.50	1.5	0.35	0.733	0.900	-0.296	0.8	0.57	1.3	0.41	1.8	0.29	1.300	0.500	0.000
0.7	0.62	1.3	0.41	1.7	0.31	1.233	0.500	-0.133	0.7	0.62	1.3	0.41	1.7	0.31	1.233	0.500	-0.133
		0.9125	0.53			0.839583	0.946875	**********			-0.01	1.00			0.070833	1.209375	0.051143
		0.60208									1.11						
		0.31042	0.81								-1.12	2.17					
		1.51458	0.35								1.10	0.47					

Figure B11. Sieve analysis

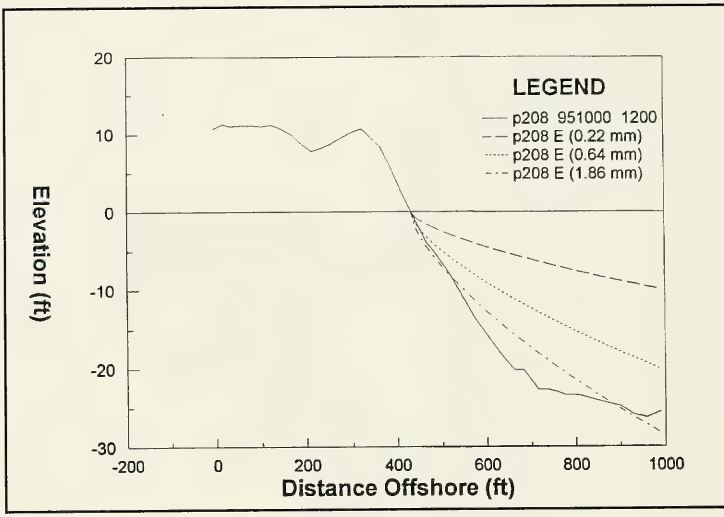

Figure B12. Beach profile equilibrium comparisons (sta 208)

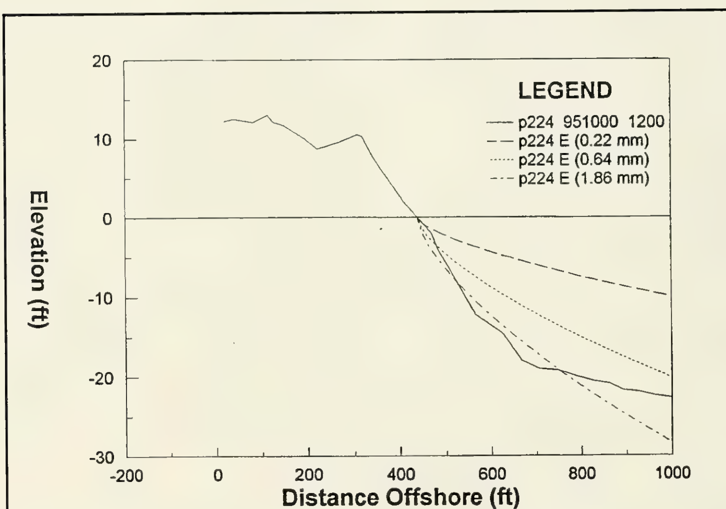

Figure B13. Beach profile equilibrium comparisons (sta 224)

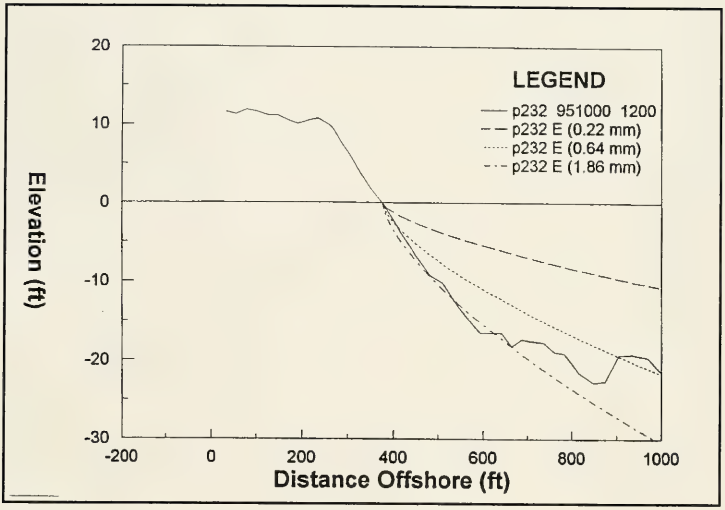

Figure B14. Beach profile equilibrium comparisons (sta 232)

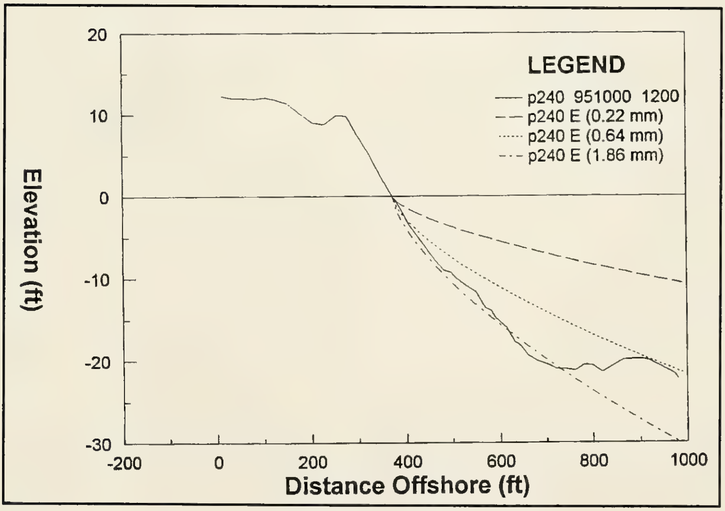

Figure B15. Beach profile equilibrium comparisons (sta 240)

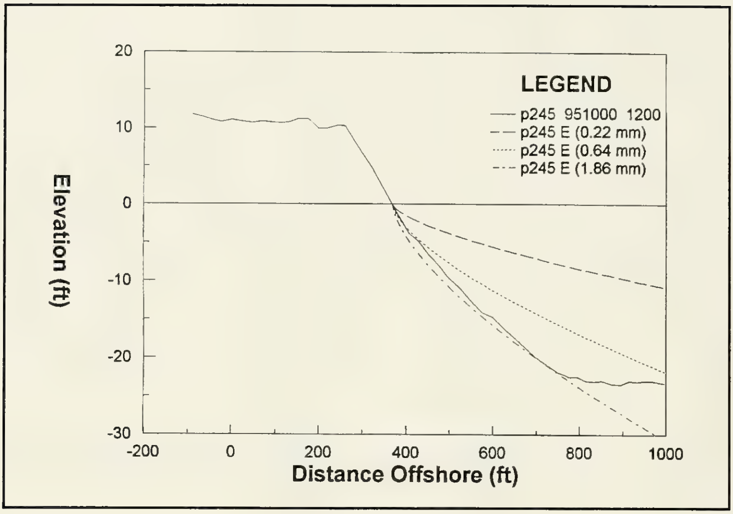

Figure B16. Beach profile equilibrium comparisons (sta 245)

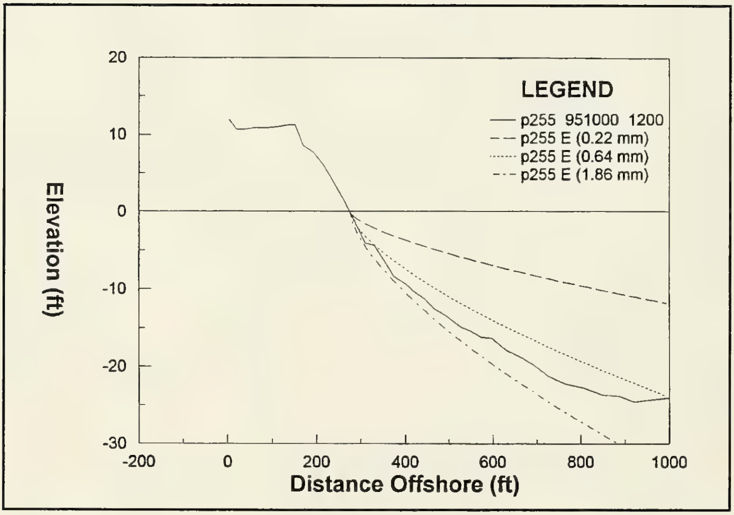

Figure B17. Beach profile equilibrium comparisons (sta 255)

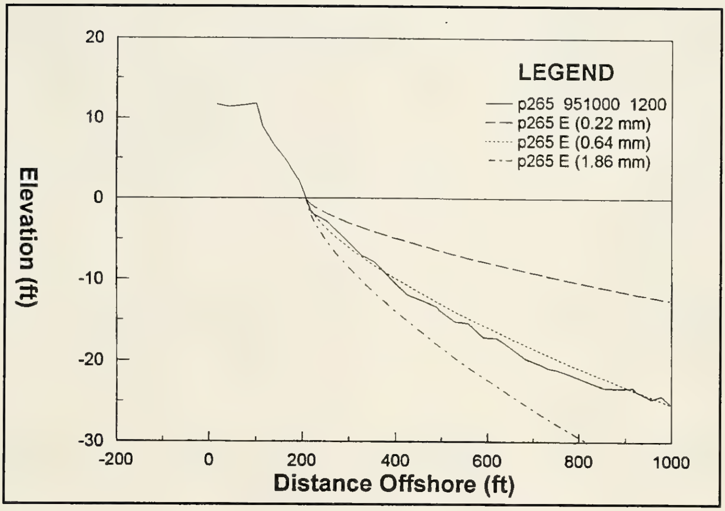

Figure B18. Beach profile equilibrium comparisons (sta 265)

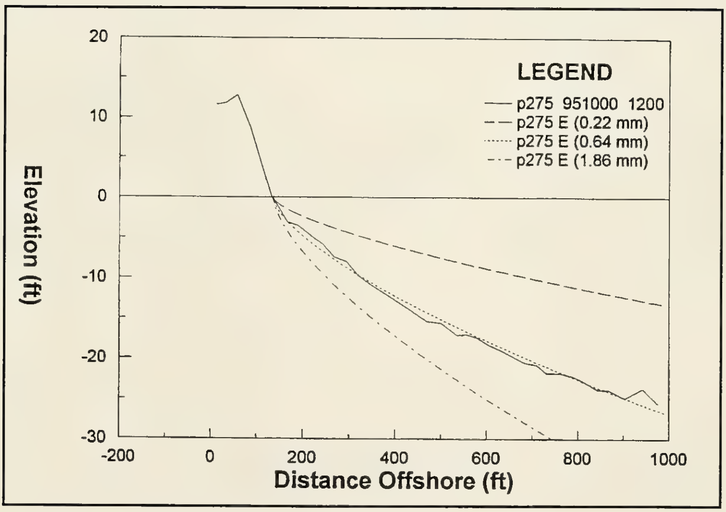

Figure B19. Beach profile equilibrium comparisons (sta 275)

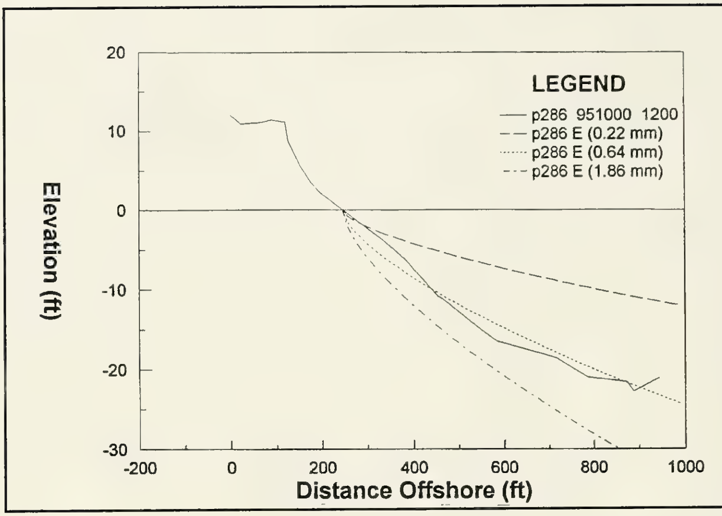

Figure B20. Beach profile equilibrium comparisons (sta 286)

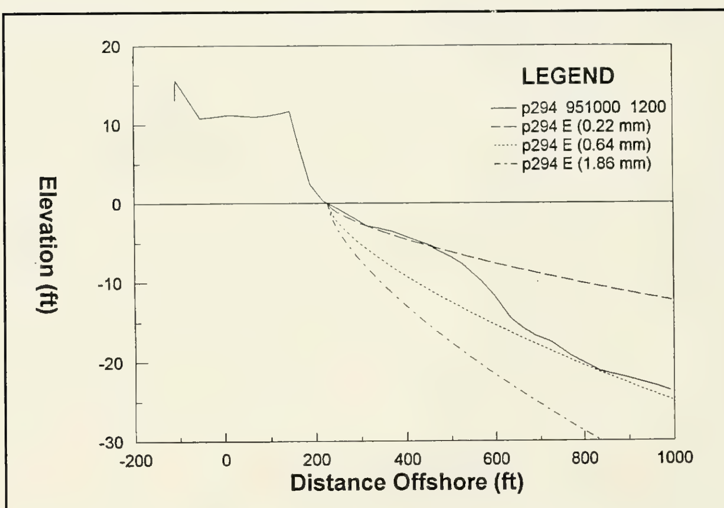

Figure B21. Beach profile equilibrium comparisons (sta 294)

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The U.S. Army Engineer District, New York, is constructing Section I-Sea Bright to Ocean Township, New Jersey, of the Atlantic Coast of New Jersey — Sandy Hook to Barnegat Inlet Beach Erosion Control Project. Within the initial portion of this project, a zone of accelerated shoreline erosion has developed near the southern boundary of Monmouth Beach, New Jersey. This report identifies sediment transport processes contributing to the accelerated erosion at Monmouth Beach by evaluating four hypotheses presented to explain the high erosion rate. Conceptual engineering actions to mitigate the high erosion rates are recommended for further investigation.

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